

Earthquake Seismograph Development: A Modern History—Part 1

Ben S. Melton

The years from 1948 through 1978 saw numerous changes in electrodynamic-type earthquake seismographs. During this period, these seismographs and their associated amplifiers, recorders, timing systems, and power supplies were subjected to worldwide service under many operating conditions. These developments required end to end understanding of the fundamental limitations on design, ultimately allowing small but adequately sensitive instruments to be built for installation in cased holes, thereby avoiding undesired local surface disturbances. The recording system developed within this period permits ready review and compact storage of seismological data.

Introduction

This history of development of modern earthquake seismographs covers the period from 1948 through 1978. This author's involvement with many decisions and occasional contributions is documented by personal records and some published reports. Some personal recollections of several individuals who were involved over the same period of years are included. All of the well-known American seismologists who were active during that period influenced and supported the development by their advice, so the engineering advances described here were of a nature to forward the seismological art in a practical manner.

In writing such a history, one needs to compose a presentation easily followed by the reader rather than to follow a strict outline of dates. My choice is to present first the sequential history of seismometers, followed by that of amplifiers, then recorders, and finally, timing systems. This involves a slight repetition of material for the case in which a modular has become a part of the seismometer, but in general, the sequence of developments was independent for seismometers, amplifiers, recorders, and timing systems. However, because of the length of this chronicle it has been separated into two parts. The first part will cover seismometers, the second, the remaining components. For the reader's convenience, the figure numbers will continue through the second part, which will be published in a forthcoming issue.

Prior to 1948, earthquake seismology in this country had an academic background. As a rule, a seismologist would purchase or have built a seismograph instrument or instruments suited to his interest in particular seismic phenomena. The different apparent surface speeds of seismic phases composed of compressive and shear waves enabled him to infer the distance of a given earthquake. Characteristically, one instrument or seismometer might have a spring-supported mass constrained to move vertically and with a

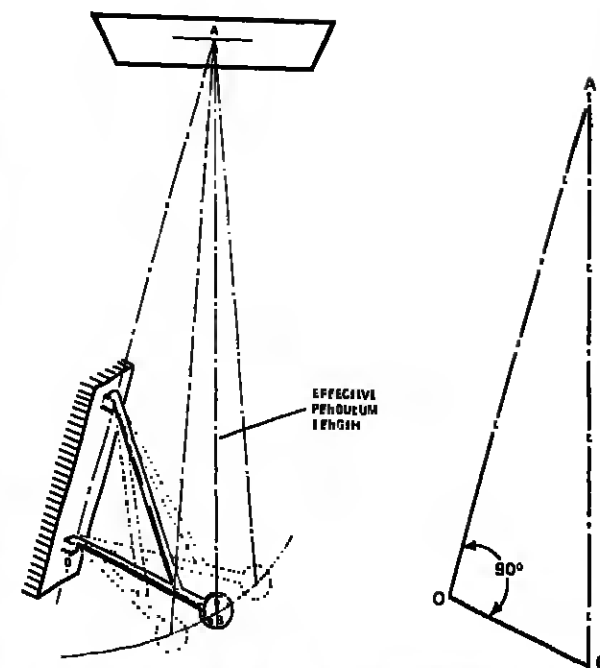


Fig. 1. Geometry of a horizontal-component seismometer, showing the relation of its hinge axis to the vertical.

natural period of about 1 s. A different instrument, or rather two more instruments, would have massess hinged on a vertical axis and constrained to move horizontally. These seismometers would be oriented so that one could respond to north-south motion, the other to east-west motion. Their periods would be on the order of 2 or 3 s, sometimes as much as 20 s. The short-period vertically responding instruments would best respond to the reflected compressive waves that travel through the earth's interior, while the horizontal mode instruments would respond to horizontal components of the longer-period shear waves.

To record distant earthquakes, the motion of each seismometer had first to be magnified by mechanical, optical, or electrical means. The early mechanical systems were easily analyzed in terms of response to earth movement, and these instruments were well covered by Dewey and Byerly [1969]. Their history of these instruments ended with the beginning of the 20th century. They mentioned the electrodynamic seismograph with galvanometer, which was introduced by Galitzin [1903], but did not discuss it.

When Prince Boris Borisovich Galitsyn (Galitzin) coupled the already well-known galvanometer to a seismometer pendulum through an electrical coil moving in a magnetic field, he laid the foundation for engineering development of the modern electrodynamic seismograph. Galitzin's galvanometer mirror or deflected a light beam which was focused on sensitized paper that was carried on a rotating drum, thereby tracing a waveform that was related to the earth's vibration. Seismologists followed this earliest documented work by devising various models for different purposes. Among better known names within this country are those of Wanner [1929], Benioff [1932], and the W. F. Sengstaken Instrument Company, Inc., of St. Louis, Missouri, which built seismometers for various seismologists. In general, the electrodynamic seismograph in use until 1950 employed this photographic registration on film or paper wound around a slowly rotating drum. The drum was translated along its axis to allow several hours of recording on the same strip or sheet. This system, the electromagnet or electrodynamic seismometer with its associated galvanometer and photographic recorder, provided high and controllable magnification of periods of interest. The seismometer could now be installed in a location less subject to nearby disturbances, and the recorder could be located more accessibly. Such was the status of most instruments in observatories before about 1950. Many observatories still use this arrangement.

However, the development of nuclear weapons after 1945, and national concerns about the possibility of clandestine tests of such weapons, led to demands for some means of detecting such tests, seismographic monitoring being one obvious choice. In 1947, Chief of Staff General Eisenhower assigned the task to the Signal Corps. With the reorganization that resulted from the emergence of the U.S. Air Force as a separate branch of the armed services later that year, the first secretary of defense, James Forrestal, reconfirmed the assignment to the Air Force Office of Atomic Energy. Funds became available to the office in 1948, and a staff of civilian scientists was assembled under a military structure. J. Allen Crocker of that staff hired this author as a geophysicist in late 1948.

Review of available information on seismographic instruments in 1948 and 1949 showed that none was adapted for rapid manufacture and standardization, which would facilitate use by anyone other than an experienced seismologist. However, basic knowledge of mechanical and electrical design was available in some government laboratories. The David Taylor Model Basin in Carderock, Maryland, a Navy facility, had already designed some 'long-period' horizontal component seismometers for use in tracking storm microseisms. These were built by Read Research Inc. of Washington, D.C. The Stanley Aviation Corporation of Denver, Colorado, was low bidder on a contract to develop 'short-period' three-component seismometers with associated amplifiers, etc., for the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Both of these systems drove Bruen Development Company electromagnet recorders through vacuum tube amplifiers.

Basic Mechanical and Seismological Problems

As distant earthquakes can produce ground vibrations with periods from a few tenths of a second to 20 to 30 s, seismometers have usually had natural periods within that range. It has been customary to have at least two sets, one set with natural periods of a second or two and another set with long-periods, sometimes 10 s or more. Two sets rather than one have been employed for sensing distant earthquakes because there exists a high and continuous vibration of the earth, called microseisms, in the period range from 3 to 8 s. These microseisms are caused by ocean wave action impinging on continental shelves.

In 1948 the microseisms were well known, but only rarely measured in amplitude at various periods and many locations, although the Navy had an ongoing study of their propagation speeds and directions relative to ocean storms. On the other hand, the natural period of the Navy seismometers was a handicap to the study of weak short- and long-period earthquake waves from great distances. Thus the scientific staff under Air Force auspices directed attention to separate seismometers for short and long periods.

Ultimately, the natural period designed into any earthquake seismometer depends upon the earth's gravity. Horizontal component instruments are designed like a 'garden gate,' that tends to swing shut because its hinge axis is aligned to intersect the vertical above the mass of the gate itself. Vertical component instruments must have a spring force that will neutralize the earth's gravity and allow the mass to have a rest position within a limited travel amplitude while sensing earth vibrations. Figure 1 shows the principle of the 'garden gate,' in which the force of the earth's field along AB is reduced by the cosine of the angle OAB. The spring force that supports the mass of a vertical component instrument should be linear with respect to spring extension, and for a simple coiled spring this becomes a large physical dimension for periods greater than a few tenths of a second. The length of a simple vertical coiled spring that supports a mass must be such that its extension E is given by the formula

$$E = gT^2/4\pi^2$$

where g is the acceleration of gravity, T is the period in seconds. Thus for a 10-s period the spring stretch E would be about 25 m. Although LaCoste had devised his long-period suspension by 1934, and LaCoste and Romberg analyzed it in their 1942 patent of a 'force measuring device,' it was not well understood by seismologists in 1948 or even much later, when LaCoste was building and selling practical gravity meters.

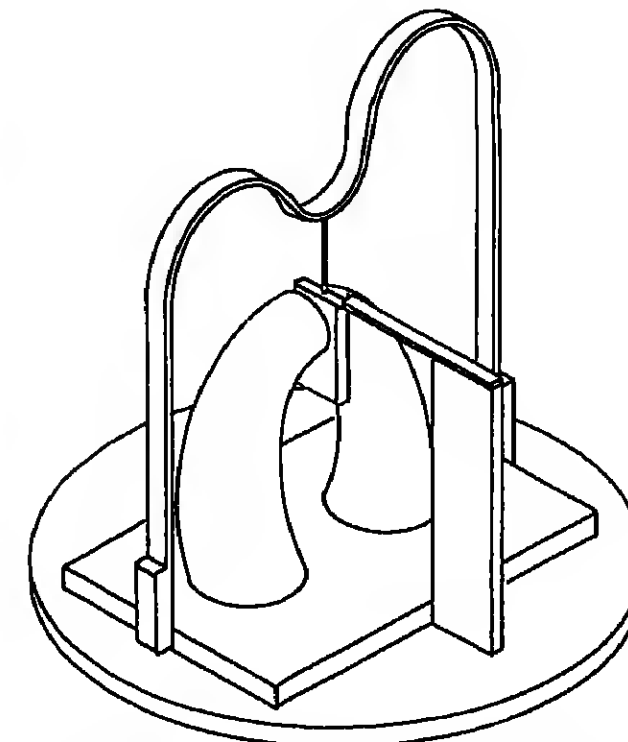


Fig. 2. Sketch of the spring suspension of the output coil of the Stanley short-period vertical-component seismometer.

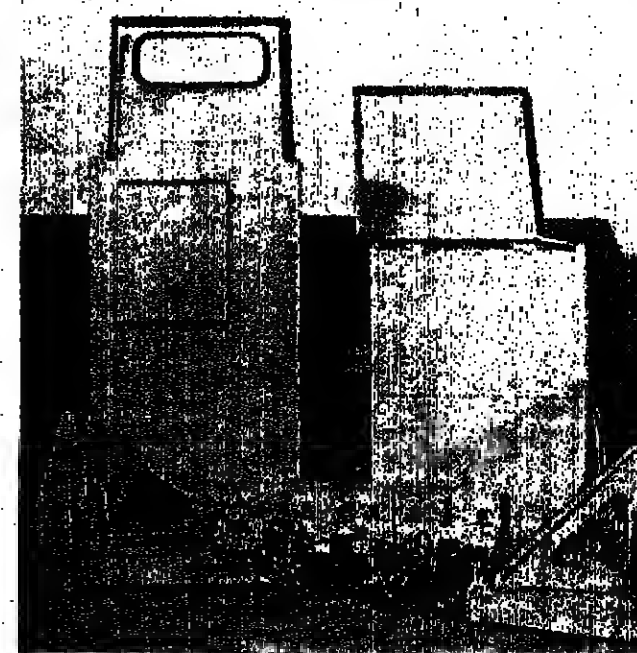


Fig. 3. DTMB horizontal-component seismograph system.

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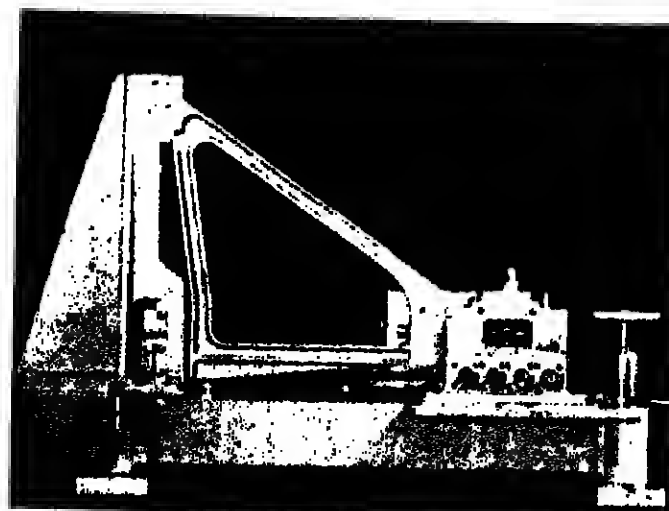


Fig. 4. DTMB horizontal-component seismometer.

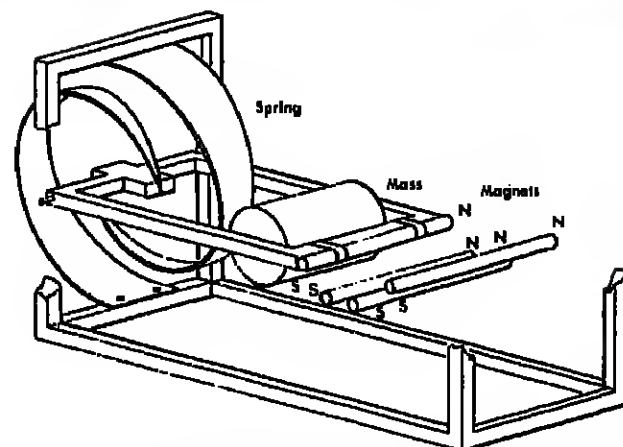


Fig. 5. Sketch showing principal construction features of the DTMB vertical-component seismometer.

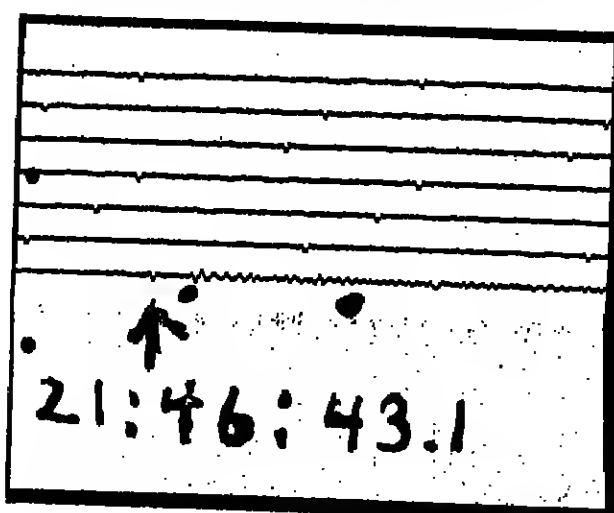


Fig. 6. Seismic record trace of the Eniwetok nuclear explosion of July 24, 1946, at 21 h 34 min 59.7 s GMT.

Early Designs of Sensitive Seismographs

The Stanley short-period seismographs and the David Taylor Model Basin (DTMB) long-period seismographs were available in 1948. The Stanley instruments provided vacuum tube amplification of the voltage generated by a coil moving in the flux field of a permanent magnet. The magnets used were surplus magnetron magnets. Use of these was a factor in allowing Stanley to submit the lowest bid to the Department of Terrestrial Magnetism (DTM). The vertical (component) Stanley seismometer used the coil as its mass. The impregnated coil was supported from a strip of spring phosphor bronze (later replaced by 'iconat') that was fastened rigidly at its ends but bent into a shape resembling a 'bishop's hat,' a name which stuck to it at the time. Figure 2 is sketched to show the essential parts of this device, which, by its nonlinear force, tended to keep its vertical dimensions within reasonable bounds while supporting the mass-coil. This arrangement was never successfully stabilized, however. The horizontal component Stanley seismometer was built on the gorden gate principle. Figure 3 shows the DTMB assembled system. The DTMB seismometers did not generate a seismic signal from a coil moving in a magnetic field. Instead, they used a capacitance bridge, one arm of which was the capacitance between a 'condenser button' and part of the pendulum. Some mechanical damping was provided by a dashpot that contained damping fluid.

The capacitance bridge network was fed by 100 kHz from a crystal controlled oscillator and buffer amplifier. When the bridge was balanced—the pendulum presumably centered in its travel—there was no signal output to an amplifier-demodulator combination. Any displacement of the pendulum unbalanced the bridge, supplying a 100-kHz signal with magnitude presumably proportional to displacement and phase depending upon direction of displacement from the balance point. A phase-sensitive detector, or demodulator, provided a signal of seismic frequency. This seismic signal followed two paths. One was through amplifiers to the Brush recorder. The other path was through yet another amplifier to a positioning electromagnet whose field was arranged to oppose the field of a permanent magnet mounted on the pendulum. Such a negative feedback reduced the natural period of the pendulum, thereby reducing sensitivity at the longer periods by selectively increasing the passband for seismic signals. Figure 4 shows the DTMB horizontal-component seismometer. The

electromagnet feedback case is back of the pendulum in this photograph.

By mid-1949 the DTMB group, under George Cook, had built an experimental long-period vertical component seismometer whose principles are illustrated in Figure 5. The spring force here was applied as a torque at the hinge end of a long arm that supported the mass, and several fixed permanent magnets offered a measure of control and stabilization by opposing the field of a magnet mounted on the seismometer arm. The centering of the mass was aided by proper positioning of magnets below the arm, and the period was affected by the magnet horizontally opposite the arm, producing periods as long as 30 s or more. The torque assembly was comprised of strips of spring metal which had low-temperature coefficients of expansion and rigidity, but the system could not be stabilized for actual service and was never developed further.

One set of the DTMB horizontal component seismographs was put into experimental field service by Baere and Heroy, a partnership between Roland F. Baere and William B. Heroy, Sr., in Troy, New York. Of that organization, staff members active today include Jack H. Hamilton, Braden B. Leichter, and Martin Gudzin, all currently associated either with Teledyne or Teledyne Geotech in Garland, Texas, hereafter referred to simply as 'Geotech.' Seismologist Carl Romney, a graduate student recommended by Perry Byerly, was with the Troy organization originally.

The DTMB seismographs were in the field near Troy, New York, and operating at the time of the magnitude 8.7 earthquake of August 15, 1950, which was located 28.5°N, 98.5°S (eastern end of the Himalayan range). But when word of the quake was received through Carl Romney, 'Brad' Leichter visited the observatory and found the operator asleep. The excuse: 'When the pens went wild, I dived it was (instrument) noise and shut it down.' However, consideration of the logistical problems involved in supplying storage batteries for vacuum tube filaments plus large quantities of dry batteries for plate current resulted in discontinuance of the manufacture and development of both Stanley and DTMB instruments. This would have happened even had it been possible to improve them. Power supplies with long-term stability and which were fed from the ac power line were not available in 1948 and the early 1950's.

Reconsiderations of Practical Seismographs and Combinations

The disappointing experience with these efforts to create sophisticated seismograph systems led to reconsideration of commercially manufactured instruments. Investigation showed that a Benioff short-period seismometer, with galvanometric registration on film, located in California, had clearly recorded the Eniwetok nuclear explosion of July 24, 1946, that was known as 'Bikini-Baker.' The print of Figure 6 shows this record section on the lowest trace. The square pulses on all traces are 1 min time marks. This record was in no sense surprising, but its existence, and political expediency, suggested that the best course was to procure and install Benioff instruments as quickly as possible. Hugo Benioff and Francis Lehner of Lehner & Griffith allowed Geotech to update manufacturing drawings, and Geotech put both verti-

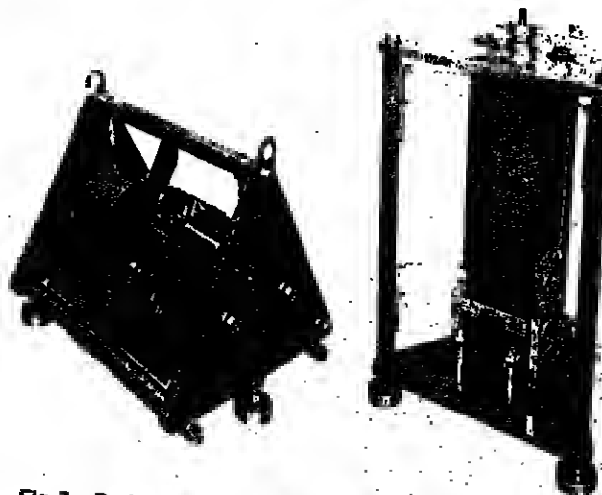


Fig. 7. Benioff short-period seismometers: (a) vertical component, (b) horizontal component.



Fig. 8. Johnson-Matheson seismometer and case.

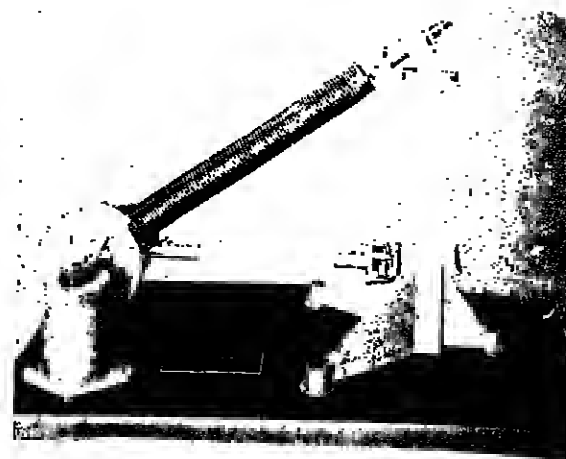


Fig. 9. Prees-Ewing long-period vertical-component seismometer with LeCoste suspension.



Fig. 10. Geotech long-period vertical- and horizontal-component seismometers.

cal and horizontal seismometers into production. These versions are shown in Figure 7.

Benioff's original paper, published in 1932, pointed out that the instrument's magnetic structure (technically, a 'variable reluctance' structure) had the effect of reducing spring stiffness, thereby shifting the natural period slightly above a half second. Also, that paper discussed the advantages of using a long-period (i.e., 14-s) galvanometer with his short-period seismometer. By 1957, Benioff had put in service a seismograph designed to respond to the normal dilatational modes of the earth's vibration. He housed one of his variable reluctance seismometers in a stiff cylindrical steel chamber to reduce its response to barometric pressure variations. To this seismometer he connected a galvanometer that had a natural period of approximately 10 min. The seismometer period was adjusted to about 2 s. The external critical damping resistance of the galvanometer was 135,000 ohms, and the transducer winding had a resistance of 135,000 ohms. To reduce the response to short-period waves, a capacitor of 200 μF was shunted across the transducer, followed by a 135,000-ohm resistor in series with the galvanometer. This arrangement makes the response constant to ground displacement within ±3 dB from 2 to 6000 s. When capacitor and resistor are removed, response to velocity is constant over the same range. However, today's negative attitudes about galvanometers have tended to close this avenue, even though it was investigated by Wanner [1929] and reinvestigated by the National Bureau of Standards (NBS) about 1960, in a study by D. P. Johnson and H. Matheson of the Bureau.

In addition to their theoretical studies, Johnson and Matheson, with the aid of master machinist Harry A. Schmidt, also of NBS, designed a short-period vertical component seismometer in which the permanent magnet was used for the mass, while the electrical coil was mounted in the frame. Figure 8 shows this instrument. A period of 0.8 s was achieved by supporting the magnet mass from three levers, which reduced the force of very stiff springs. The springs were made very compact and could be given a prestretch in their normal position. The effect of spring stiffness was reduced by a factor of 10 in this manner; this was equivalent to making the springs 10 times as long. These instruments were quite rugged, and some of them eventually replaced the vertical component Benioff seismometers. Some details of this instrument were shown and discussed by Melton and Johnson [1982].

NBS Report 7454 was first issued in 1962. The final document, NBSIR 76-1089, was issued in 1976; but the report never entered the public literature because its authors declined to discuss earlier papers covering the same material, in lieu of such discussions they defined all of their variables and included those of the earlier literature, where appropriate, for the reader's reference.



Fig. 11. Geotech Model 7505A seismometer, showing modern suspension until on back side of hinge.

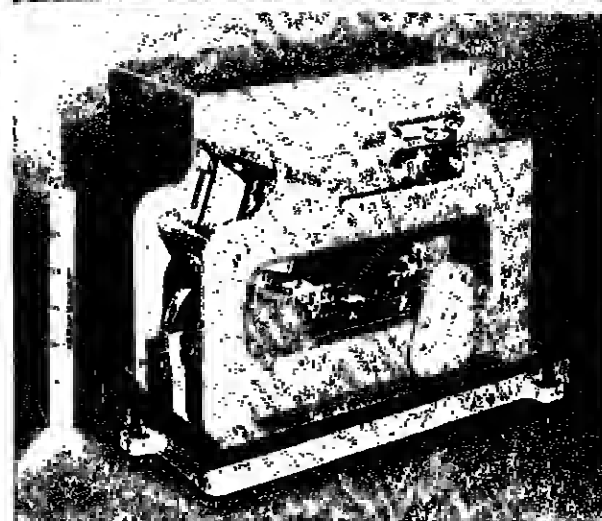
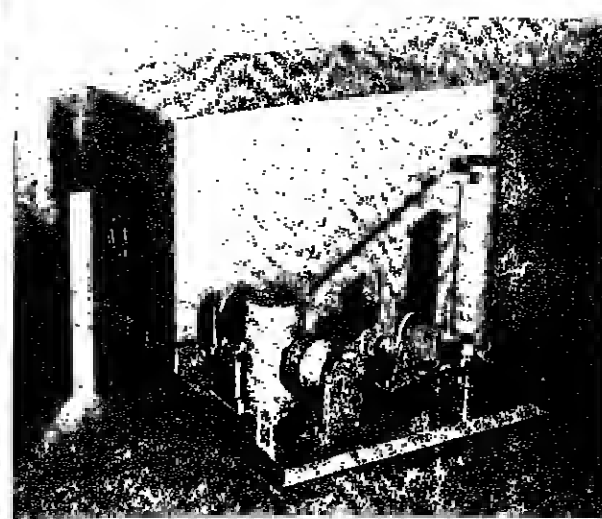


Fig. 12. Sprengnether long-period seismometers: (a) vertical component, (b) horizontal component.

During the study of this seismometer and others there was much discussion of how small a mass could be adequate. Clearly, the greater the mass, the more energy available from earth vibrations to be recorded. Also, the instrument self-noise power was believed to be inversely proportional to the mass. Both considerations suggested that there should be a minimum acceptable mass. Wolf discussed this in 1942. Byrne in 1961, and Johnson and Matheson about the same time. With these studies and other factors in mind, the 18-kg mass of the NBS seismometer was thought to be just adequate. Only years later did review of earlier published theory, by O. D. Sierkey of Geotech, Block and Moore [1966, 1970], and the present author, establish the fact that the damping energy was the only source of thermal noise—the ultimate limit of useful sensitivity.

Of course, the total damping energy depends on the mass, so the mass is very small, the absolute damping must be very low—affatively, the 'Q' must be very high. Also, it should be noted that the external damping power of an electrodynamic seismometer provides the only means of registering its motion or, equivalently, transferring information outside the instrument. The internal damping, including coil losses, does not transfer information. This theory and supporting earlier experiments were covered in a review paper by Melton [1976].

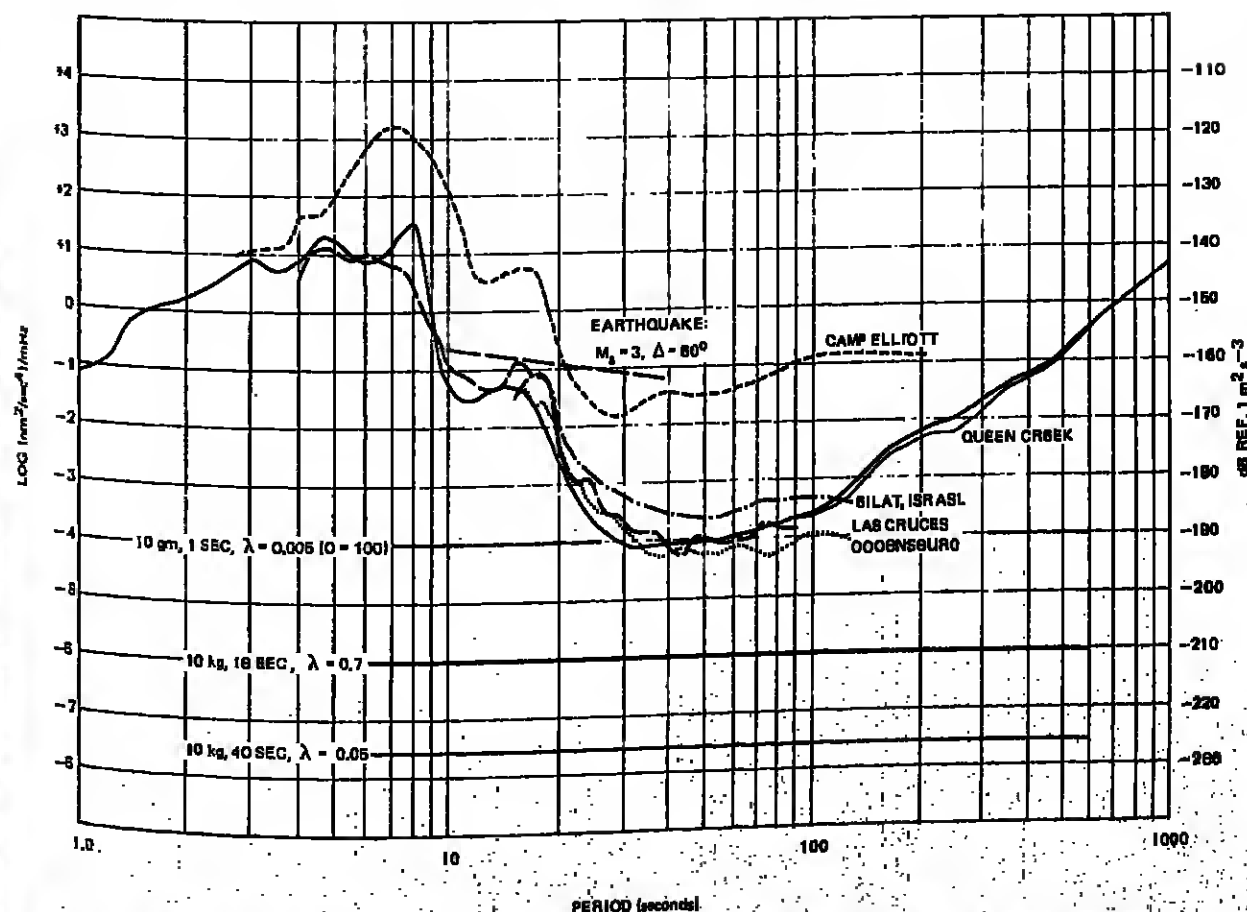


Fig. 13. Medium- and long-period spectra of earth noise plotted as squared acceleration per millihertz. The Queen Creek spectrum, after Fix [1972], is shown with two branches, the thin line lower branch representing the noise after subtraction of the measured instrumental noise included in the upper branch. Elsewhere along this curve the instrumental noise is a negligible portion of the energy represented. The Camp Elliott curve, after Haurich and MacKenzie [1966], represents data from a southern California site about 20 km from the West Coast. References for the other curves are as follows: Las Cruces, New Mexico, Trif [1966]; Oodenburg, New Jersey, Savino et al. [1972]; and Bilat, Israel, Murphy et al. [1972]. Thermal acceleration energy for several assumed seismometers is shown by the horizontal solid lines, and a proposed frequency plot of an earthquake with surface wave magnitude of 3 at 60° epicentral distance is included in order to show the relation between earthquake and noise energy.

Earthquakes and explosions both produce seismic body and surface waves; however, explosions generate relatively weaker long-period surface waves than do earthquakes. Thus to distinguish between earthquakes and explosions, long-period seismometers are desirable in association with short-period seismometers, but experience with the DTMB instruments discouraged development until Ewing and Press [1953], at the Lamont Geological Observatory of Columbia University, put into service a long-period vertical component seismometer that was built by Lehner & Griffith of Pasadena, California. Figure 9 shows this instrument, which was compensated for varying air buoyancy by an outrigger hollow sphere which had a volume equal to that of the seismometer's inertial mass. This instrument employed the LeCoste 'zero-length spring' suspension, thereby emphasizing its practicality. However, the seismometer was not shielded against air currents or insulated against temperature changes.

The need for temperature stability and insensitivity to air currents and barometric pressure changes called for an enclosed design for production. Accordingly, Geotech provided a design with a base and an airtight heavy case of Mahanite, a cast-iron alloy, which was clamped into a gasket around the perimeter of the base. The long-period vertical component was manufactured as Geotech Model 7505A. The associated horizontal component was Model 8700C. Both models are shown in Figure 10. The vertical component shown in Figure 11 has a balancing weight whose position can be changed by a motor drive that adjusts the mass' rest position' to its center of travel. This model worked well at natural periods up to 15 s, but many instruments were unstable at periods greater than 20 s, chiefly because the LeCoste design was neither well understood nor well executed, and partly because of unsuspected paramagnetism of the electrical coil form, which was later corrected. These instruments were put in service late in 1962. The problems with these instruments resulted in publication of the Melton [1971] paper on the LeCoste suspension.

Sprengnether also built modern vertical and horizontal long-period seismometers, which are shown in Figure 12. In a well-protected environment these instruments serve as well as those of Geotech. In 1952, Sprengnether long-period vertical and horizontal component seismometers were installed as part of the World-Wide Seismograph System operated by the Coast and Geodetic Survey of the U.S. Department of Commerce. The vertical seismometers have a temperature compensator to adjust for gradual temperature changes, and both vertical and horizontal instruments are provided with metal covers with heaters and expanded polystyrene covers over the metal. These covers are not sealed however.

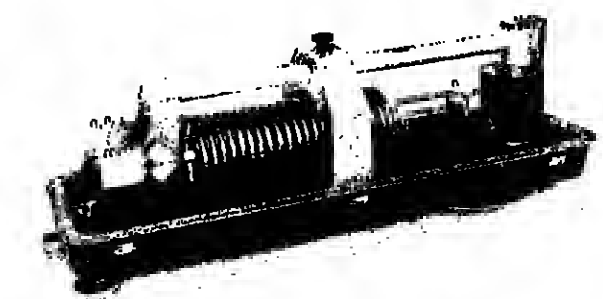


Fig. 14. Melton variable period seismometer.

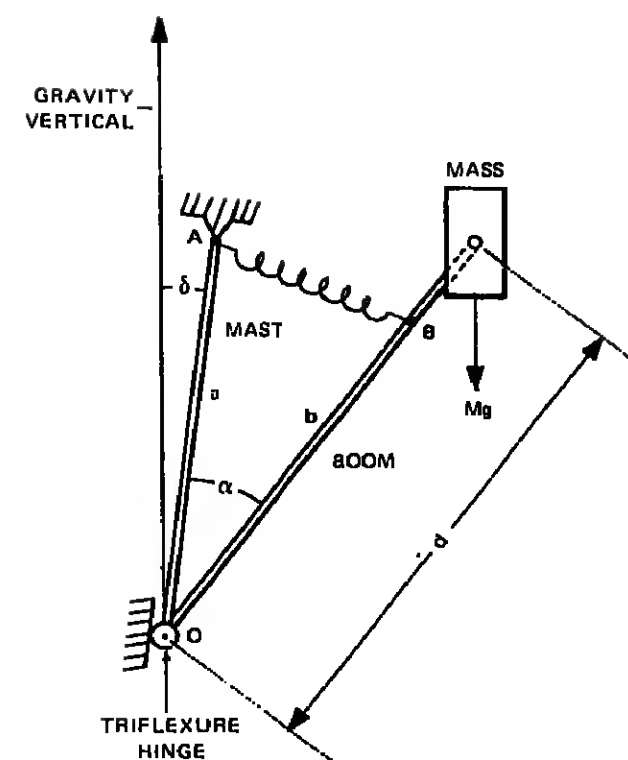


Fig. 15. LeCoste suspension as employed in the symmetrical triaxial seismometer; θ represents the angle of tilt.

Justification of the Mass Requirement for the Electrodynamic Seismometer

Throughout the period covered by this history, justification of the magnitude of the seismometer's inertial mass was a major concern. The mass had to be sufficient to deliver adequate energy for recording minimal earth vibrations. On the other hand, an oversize mass would increase problems of handling and shipping.

In 1963, using NBS Report 7454 as the reference, I made calculations to determine the minimum acceptable mass for a seismometer designed to detect weak long-period earthquake waves. The practical example taken was a 10-kg mass seismometer, which had a natural period of 15 s, closely coupled to a galvanometer that was recently designed by Forest K. Harris of NBS. That galvanometer had a natural period of 100 s and a moment of inertia of $4 \times 10^{-6} \text{ kg m}^2$, and it was to be used in a phototube amplifier, a device which will be described in part 2 of this history.

In NBS 7454, ω_n , ω_d , and ω_m refer to the natural angular frequencies (radians per second) of the seismometer, galvanometer, and geometric mean of these frequencies ($\omega_n \omega_d \omega_m$)^{1/2}, respectively; ϕ is the ratio $\omega_n \omega_d \omega_m$, where ω is the variable; λ_n , λ_d , and λ_m refer to fractions of critical damping for the seismometer, galvanometer and geometric mean ($\lambda_n \lambda_d \lambda_m$)^{1/2}, respectively; y is taken as earth displacement, and θ refers to the angular deflection of the galvanometer coil, so the fraction y/θ represents the earth displacement in meters per radian of coil deflection. Similarly, a fraction M/K is the ratio of seismometer mass to galvanometer moment of inertia.

Equation (B.3.22) in NBS 7454/NBSIR 76-1089 is

$$4\lambda_m M/K (y/\theta)^2 = \phi^{-2} + \phi^2 + B^2 - A^2$$

where

$$A^2 = 2(\omega_n^2 + \omega_d^2)/\omega_m^2$$

and

$$B = (8 + A^4)/8A$$

As all quantities on the left side of (B.3.22) are real and positive, physical reality demands that the right side must be positive for all values of ϕ . The minimum value of $\phi^{-2} + \phi^2$ occurs at $\phi = 1$ and is 2 . For the problem at hand we can take ω at midband, so that $\phi = 1$. Then, substituting the angular frequencies, we find that $A^2 = 13.64$, $B^2 = 43.13$, so that

$$4 \times 0.8^2 M/K (y/\theta)^2 = 2 + 43.13 - 13.64 = 31.49$$

and

$$y = 3.51 \theta (M/K)$$

Substituting the seismometer's 10-kg mass and the galvanometer's moment of inertia $4 \times 10^{-6} \text{ kg m}^2$, we obtain $M/K = 10^{-7}$, so that

$$y = 2.22 \times 10^{-3} \theta \text{ meters}$$

Experience had shown that we could observe and record a galvanometer angular deflection of somewhat less than a microradian by using a phototube amplifier with a good power supply. Taking $\theta = 1 \times 10^{-6} \text{ rad}$, we have $y = 2.22 \times 10^{-9} \text{ m}$ at a period of 38.7 s.

When the above calculations were made, there was little information on the expected amplitude of microseismic noise at the longer periods. The data of Trif [1965], Savino et al. [1972], Murphy et al. [1972], and Fix [1972] were not available. These data were reviewed and collated by Melton [1976], and it is interesting to reexamine the choice of a 10-kg seismometer mass with the long-period galvanometer, in light of the later information.

Unfortunately, the spectral analysis presentation of a statistical sampling procedure masks the fact that at any given time the microseisms are nearly sinusoidal and mostly at one period. Similarly, earthquake waves usually have a maximum amplitude at some period that changes slowly, and it is this amplitude upon which detection depends. Therefore, we need to realize how microseisms over a narrow band are translated into a statistical value taken over a long time.

Earth Noise Studies

As late as 1958 the seismological literature disclosed very little information on the amplitude of microseisms and cultural noise relating to geology, geography, time of year, or frequency of occurrence. However, in 1949 the Naval Ordnance Laboratory (NOL), located in White Oak, Maryland, was assigned to investigate these phenomena. No instruments were available for this study, so a laboratory group under the direction of J. V. Atanasoff, later directed by Ben Sneyd, undertook to build small vertical and horizontal component seismometers for field deployment. These little seismometers, designed to go down a hole, used masses of about 100 g. Most of the suspended mass of each instrument was in a flat plate centered between two fixed plates, and the combination formed part of an electrical bridge that controlled the phase of a high-frequency carrier current, which was amplified and demodulated to give the low-frequency seismic signal output. The mass/plate of the horizontal component instrument was mounted on the top end of a thin flat spring. The vertical component mass/plate was also attached to a flat spring member, but a vertical coil spring was added to offset gravity. Both components had a natural mechanical period of about 1 s. A patent issued to Atanasoff and Kolarud in 1956 reveals the details.

These instruments employed electrostatic forces to modify their response. A controllable dc potential difference between moving and fixed plates served to decrease the effective spring rate (restoring force), thus increasing the period to several seconds. Biasing this potential in favor of one or the other fixed plate served to recenter the moveable plate. This recentering bias was provided by a long time-constant (~200 s) integration of the demodulated signal output, thereby reducing long-term drift. The demodulated signal output was also differentiated and fed back to provide controllable damping. The amplified signal output of each seismometer drove a galvanometer that deflected a light spot on photographic film, which was translated to provide the time axis. Also, the amplified signals were fed to Esterline-Angus chart recorders to monitor seismometer operation.

The NOL seismographs were deployed late in 1949 and were operated by military personnel through much of 1950, serving to relate microseisms of different frequencies to different times, as oceanic storms varied conditions of generation. However, these instruments were critical in adjustment, both mechanically and electrically, and not well suited to unattended operation. Also, their locations were restricted because they had power supplies that required connection to a commercial power line.

As experience was gained in siting seismometers for earth noise studies, and as more observatories were set up at numerous geologic locations, the construction of seismometer vaults was found to be important. Finally came the realization that even a concrete vault beneath the surface required a means of entrance which, if part of the structure, coupled the entire vault to the surface of the earth, thereby transmitting surface disturbances to the seismometer. Therefore, consideration was given to designing seismometers that could be put down a deep hole and adjusted, as necessary, by remote controls.

Accordingly, efforts to measure local earth disturbances as a function of depth were begun under a contract with United Electro Dynamics Corp. (UED) to put a seismometer at different depths in some abandoned oil well hole end to measure the noise at each depth in comparison with the noise at the surface. Shell's Government No. 1 well near DuBois in Fremont County, Wyoming, was chosen for this study, which began in late 1958. Many troubles were experienced with the instrument sent downhole, and the mud level sank continually. Only in 1960 were results obtained that seemed to indicate the expected reduction of noise as compared with standard instruments installed on the surface near the well. The well study was terminated in April 1960, but John Woolson of UED made further noise measurements for various geological surface conditions and sites for a number of months thereafter and on into mid-1961. Also, there were several attempts to correlate microseisms between sites separated by about a half kilometer or more. Spectral analysis was done by analog methods, by moving a filter band over a repeated sample of the noise on magnetic tape, this at higher tape speed in order to bring the signals into the audio band.

The well measurements were only the forerunners of later studies too extensive to discuss at length. In mid-1962 a variable reluctance seismometer, based on Benlioff's design, was devised specifically to lower into deep wells for these studies.

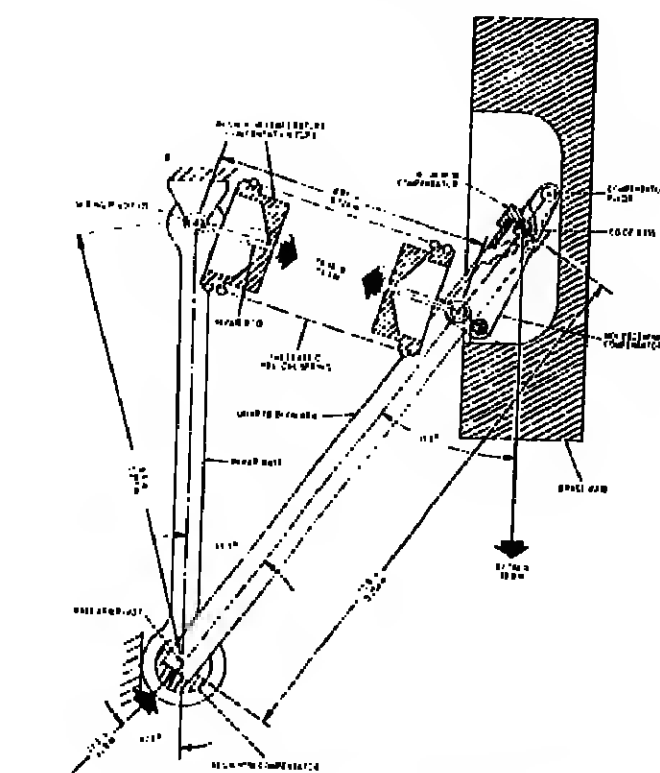


Fig. 16. Construction of Le Coste suspension in one element of the triaxial seismometer.

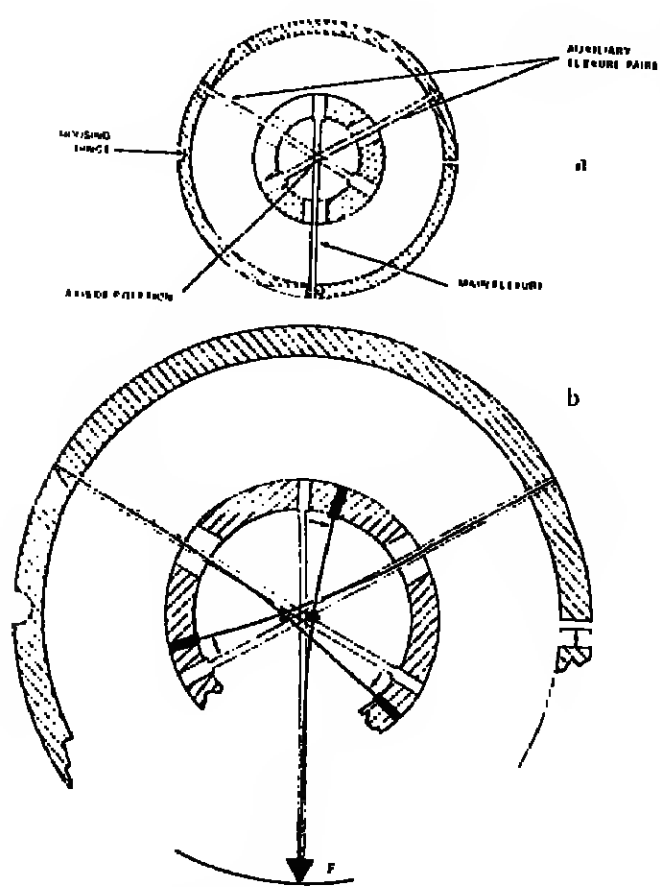


Fig. 17. (a) Basic configuration of triflexure hinge. (b) Introduction of force couple as inner member is rotated. Forcing open the outer housing at the slit on the right produces a tension force F . As the crossing point of the flexures moves away from the central axis, the force F tends to produce further rotation. The net result is to increase the seismometer natural period.

Consider Figure 13, which is reproduced from Melton [1976], and examine the region which shows curve maxima from 12 to 18 s. This curve should be interpreted simply as picturing a high probability that nearly sinusoidal microseisms will appear in this band, and by the same token they reduce the probability of earthquake wave detection in this same band. As we cannot validly reduce any statistical value of average energy to some specific value of energy at a single frequency, we must choose a bandwidth for conversion purposes. Based on comparisons of early visual measurements of microseismic amplitudes to the later statistical frequency analysis, my compromise choice is one-third octave.

Therefore, in the passband from 15 to 100 s, microseisms at 20 s or less should reduce the probability of detection over, say, a one-third octave band centered at 17 s, 13.6 mHz. Taking an arbitrary value $1 \times 10^{-1} \text{ (nm}^2 \text{ s}^{-4})/\text{mHz}$, we have for one-third octave a mean square acceleration of $1.38 \text{ nm}^2 \text{ s}^{-4}$ and an rms acceleration of 1.17 nm s^{-2} , which corresponds to an rms amplitude of 2.72 nm at 17 s or a peak-to-peak amplitude about 3 times that value, or 8.15 nm.

Thus, if we accept a detection amplitude value of 2.22 nm over a flat passband from 15 to 100 s, we can conclude that the seismometer-galvanometer combination considered above has a high probability of having an adequate detection capability. However, in any real system the seismometer would be connected to the galvanometer through a resistive network that has some minimal loss, so prudence suggests that choice of a much smaller seismometer that has a lower moment of inertia were chosen also. For example, a Lehner & Griffith galvanometer Model GL-281 has a moment of inertia of $2.6 \times 10^{-7} \text{ kg m}^2$.

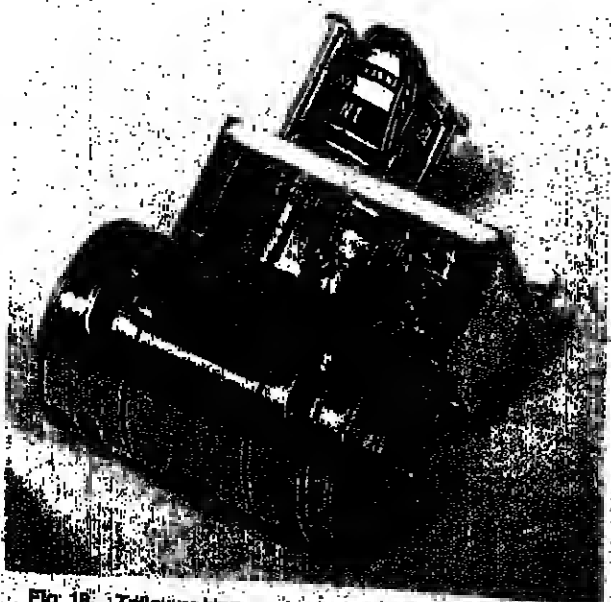


Fig. 18. Triflexure hinge and motor assembly. The reversible motor serves to adjust the tension F , shown in Figure 17, thereby controlling the seismometer period.

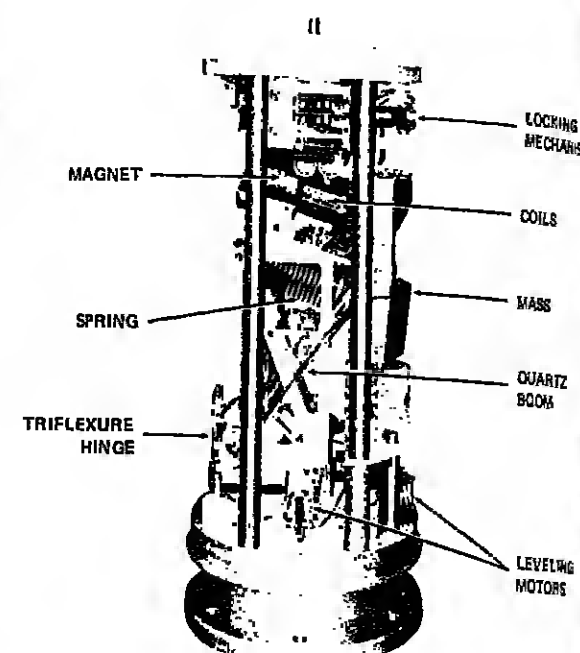


Fig. 19. Single module of the triaxial seismometer.

This instrument had a 100-kg mass and provided sufficient electrical output to ensure adequate sensitivity for measuring a very low noise field at great depths. The first well surveyed, Magnolia's Trigg No. 1, was located in the northeast part of Tarrant County, Texas, on the present site of the Dallas-Fort Worth airport. The well was about 3000 m deep, bottomed in limestone.

The Variable Period Seismometer—Its Concept and Use

In 1959 the author suggested, with a construction sketch, that a variable period seismometer be devised for use by any seismologist for his particular interest. The concept was to provide the critical parts un assembled, to be put together by the individual seismologist. However, funds were unavailable until later, when discussions of the atomic test ban took place and the USSR representatives offered some of their seismometers for comparison. As there were no comparable American seismometers available, funds were provided, and the Melton seismometer (Figure 14) was created. In this seismometer the 5-kg mass can be moved to or from the hinge, and the spring tension can be adjusted by stretching or releasing the spring. A steel tape attached to the spring is wound on or off a drum through a worm and gear mechanism for this adjustment. The natural period is variable from 0.5 to 7 s, while the electrical circuit resistance required for damping remains nearly constant. Hamilton and Stephens [1962] mention that this instrument was installed at the Dallas Seismo-

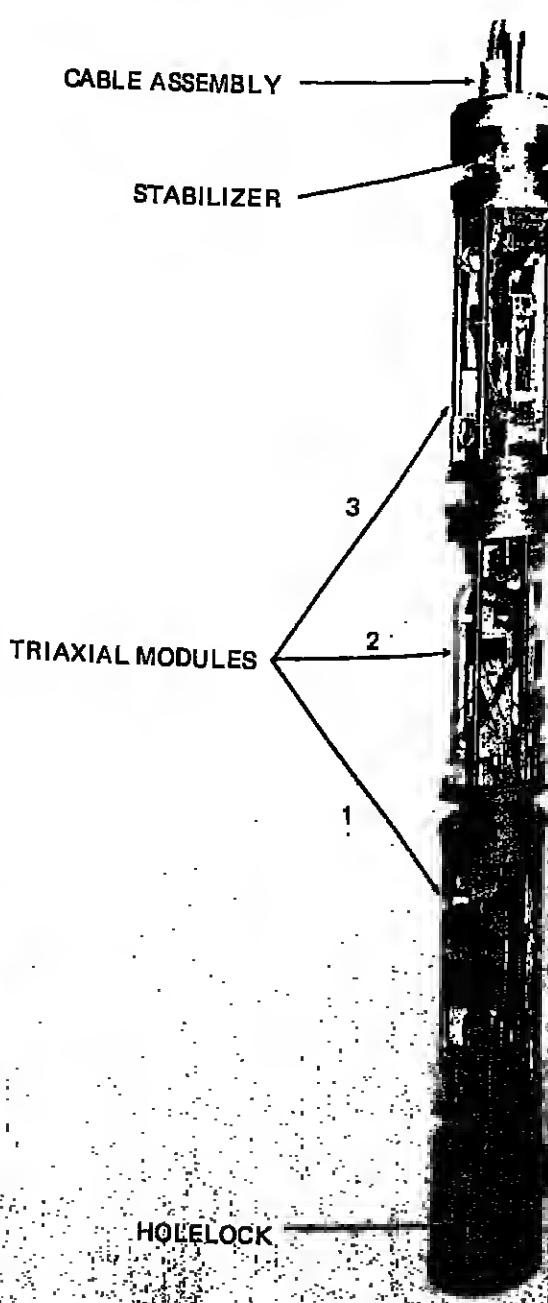


Fig. 20. Uncased assembly of the three modules of the seismometer, together with a holelock mechanism below and leveler above.

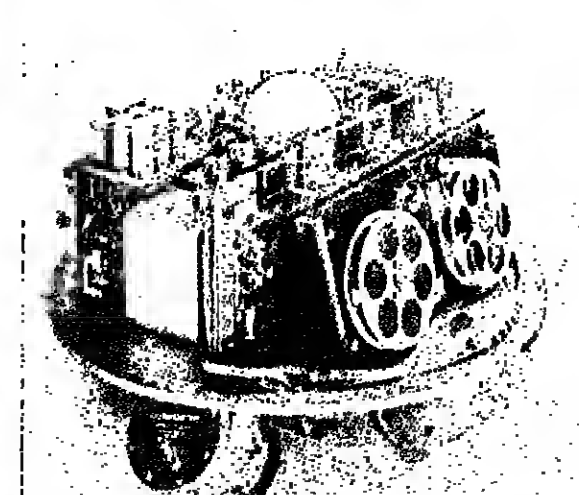


Fig. 21. Ocean bottom seismograph developed for the Scripps Institution of Oceanography.

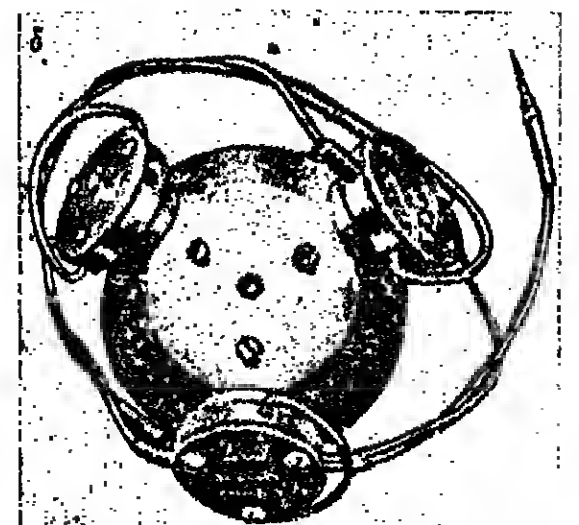


Fig. 22. Russian geophysical prospecting seismometer showing symmetrical triaxial arrangement of three of its sensors.

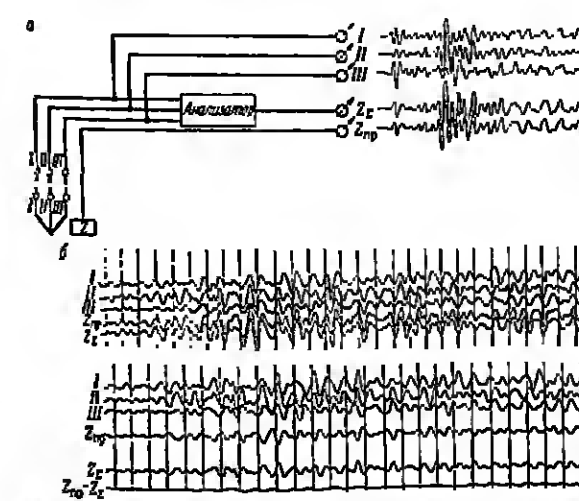


Fig. 23. Signal traces from the four sensors of the Gel'perin seismometer arrangement.

logical Observatory at Southern Methodist University (SMU) to provide a flat "velocity" response over the period range from 1 to 100 s.

The Symmetrical Triaxial Configuration

Emphasis on adequate identification of long-period earthquake waves influenced the next development. The instrument was described and patented as an 'Angular Composite Seismometer,' but it became known as the 'Symmetrical Triaxial Seismometer.' In such an instrument the orthogonal directions of response form equal angles of about 55° with the vertical. These orthogonal directions permit sensing acceleration components that can be rotated subsequently to the conventional horizontal and vertical directions, provided the physical orientation of the instrument is known. The advantage of such an arrangement is that all three spring-mass systems are designed identically, giving greater assurance of matching characteristics. Also, as the arm carrying each mass is within about 35° of the vertical, the horizontal dimension can be less. Then stacking the three elements vertically permits a slim design, suited to putting down a hole.

My notes show that this composite seismometer was described to an associate on March 7, 1960. The ultimate mechanical design by Bernard Kirkpatrick of Geotech was underway in 1966, and an array of these instruments was being installed near Fairbanks, Alaska, in late 1968. The patent was filed in 1963 and issued December 7, 1985. The individual element masses were 10 kg because we had no assurance at the time that a lighter mass would be adequate. Each LaCoste suspension was designed and adjusted to the 'infinite period' position. Then the period was adjusted by changing the tension on a special triflexure hinge by way of a motor drive. Figure 15 diagrams the LaCoste suspension. The angle θ is zero for 'infinite period.' Figure 16 shows the basic construction of one element. Figure 17 illustrates design principles of the triflexure hinge. Figure 18 shows the hinge and motor assembly. A more complete description is given by Melton and Kirkpatrick [1970]; Weinstein [1965]

discusses hinges of this general type as 'flexure pivot bearings.'

Figures 19 and 20 show a single module and an uncased assembly of three modules with holelock underneath and a stabilizing device at the top. These instruments showed greatly reduced response to local surface disturbances caused by wind and atmospheric pressure variations, even though in some installations the depth was much less than planned, because of drilling problems.

The symmetrical triaxial configuration was incorporated into an ocean bottom seismograph developed for the Scripps Institution of Oceanography by Earth Sciences Division, Teledyne Industries. Figure 21 shows the uncased assembly.

The symmetrical triaxial principle has also found its way into geophysical prospecting. Gel'perin [1977] has published a book which describes a polarization scheme of recording all types of waves simultaneously. In this scheme, four sensors are used. Three of them are oriented triaxially, as suggested in Figure 22. A fourth sensor responds as an independent vertical component. Figure 23 shows signal traces from these elements. Trace Z_1 is evidently the effective vertical formed by direct summation of the triaxial component signals, while Z_2 is the independent vertical signal. The Z_1-Z_2 trace, if quiet, indicates a true amplitude match of the vertical component signal amplitude to the signal composed of the triaxial sensors and implies proper calibration of all sensor outputs.

Principles and Practices for a Radically Different Seismometer Design

Even as the asymmetrical triaxial was being developed and put in service, a new concept of mass-thermal noise relationship was evolving. The realization that the thermal noise of a seismometer depended on its damping losses (rather than on its mass) suggested that a much lower mass and smaller seismometer could be devised, provided that amplifiers could compensate for reduced seismometer outputs. Briefly stated, the thermal noise (force) of a periodic system, electrical or mechanical, resides in its lossy elements. The system oscillations indicate the presence of some force, including thermal noise, but the amplitude of mass (or spring) oscillation is only a measure of energy, not the energy source itself.

O. D. Starkey of Geotech reviewed the work of McCombie [1953], Milatz and von Zolingen [1953], and Milatz et al. [1953], and by 1966 had composed a long handwritten treatise which included a 31-page section on 'Active Damping in Seismometer-Amplifier Combinations.' Block and Moore [1966, 1970] showed how active damping could be applied in designing an accelerometer, and I became fully aware of the principles in April 1970 when called upon as a consultant to evaluate the Block-Moore instrument. Essentially, the proposal was to provide a very small quartz seismometer with the desired damping—say, 0.7 critical—by applying negative

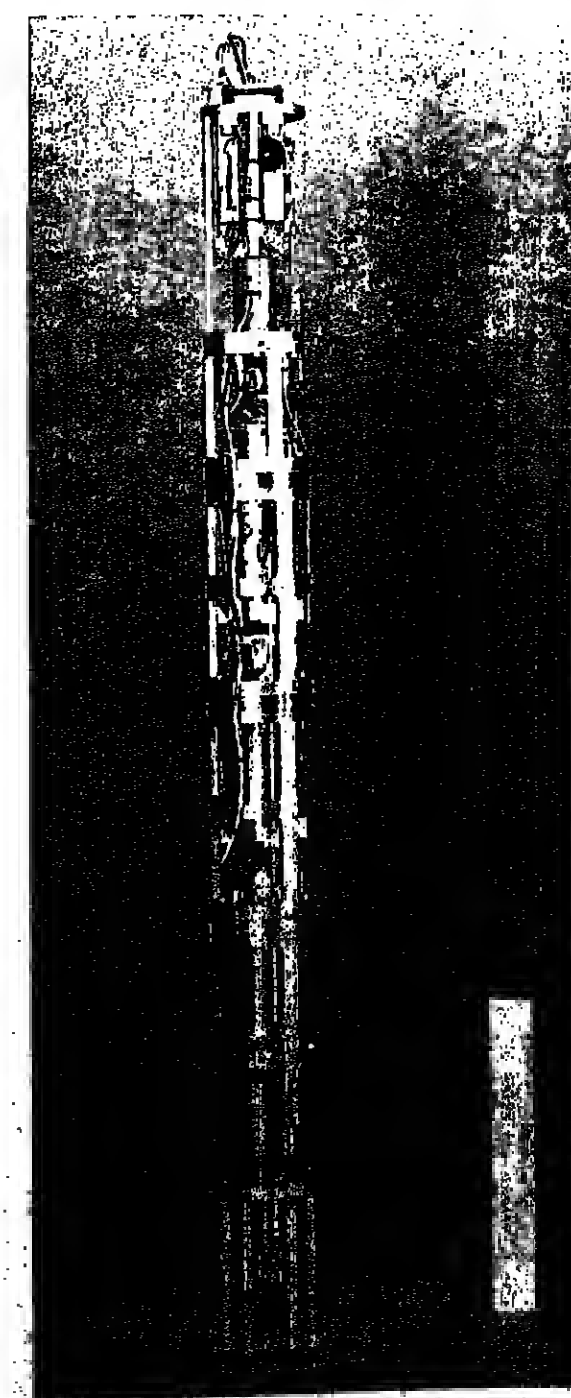


Fig. 24. Mechanical assembly of the force balance K-S seismometer, Geotech Model 36000, later known as the SRO seismograph system.

feedback force to the mass, proportional to velocity, rather than using loss damping of any nature. The little mass would be part of a capacitance bridge modulator to provide an electrical output as the mass moved. A general discussion of this arrangement follows.

We have noted that the electrical load of a conventional electrodynamic seismometer provides the information output. So, if the load is eliminated, means must be devised to sense mesa movement. This is feasible with a properly designed modulation scheme, which in itself produces negligible mechanical reaction noise. A modulator is generally understood to be a device by which a low-frequency signal modifies a high-frequency carrier. The modulated carrier can then be amplified as desired, and a demodulator can recover the amplified low-frequency component. In this manner one avoids so-called 'one-over-f' noise, a characteristic noise injected by all active devices that control dc power (that is, amplifiers) and which increases dramatically at periods greater than 10 s. Figure 31 of part 2, in the section on carrier amplifiers, illustrates this with factual data.

Application of the above principles eventually made possible the development in 1970 of a more useful 'downhole' seismometer—the Geotech Model 36000 seismometer—known locally as the 'K-S Seismometer,' after its designers Bernard Kirkpatrick and O. D. Starkey. This seismometer can be lowered inside a 7-inch (outside diameter) 20 lb/ft API



Fig. 25. Cased assembly of the Model 36000 seismometer, including downhole electronic components, ready to be lowered into a cased hole.

casing. The uncased mechanical assembly appears in Figure 24. In order, from the bottom upward, are shown the two horizontal components, the vertical component, and the air pulse mechanism. An air pulse is fed to a ball-and-socket joint at the top of each component case to free the joint momentarily and allow the case to seek a vertical position. This is necessary because, in general, the hole is not vertical. Figure 26 shows a cased assembly, including electronic components, ready to go down a hole. These seismometers were put in service in 1976 as the Seismic Research Observatory (SRO) seismograph system, described by Peterson and Orneli [1976]; Paterson et al. [1976].

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News

NSF Losing Earth Sciences Research Funds

The Earth Sciences Division (EAR) of the National Science Foundation (NSF) faces a diminishing financial base from which to award grants for research, while the proposed pressure increases. Robin Bratt, director of the division, noted, "Now that the Ocean Drilling Division has become a separate entity [within the Foundation] the Division of Earth Sciences has no major facility, and with the exception of COCORP, at \$2.8 million per year, we are a small science division, consisting of four programs—geology, geophysics, geochemistry, and petrology."

Bratt noted, however, that the field of earth sciences research, which the NSF attempts to support, has grown rapidly in the past decade. "Growth (in terms of people employed in the field) is predicted to increase markedly, as the following quotation from Science and Engineering Education for the 1980s and Beyond (NSF publication, 1980) attests:

"Among the sciences, growth (between 1978 and 1990) is put at 40% for psychologists, geologists, statisticians, and economists. Occupations with projected slow growth include atmospheric scientists, physicists and astronomers, and mathematicians, all of which are projected at 10 percent or less."

"The average grant has decreased in dollar value rapidly

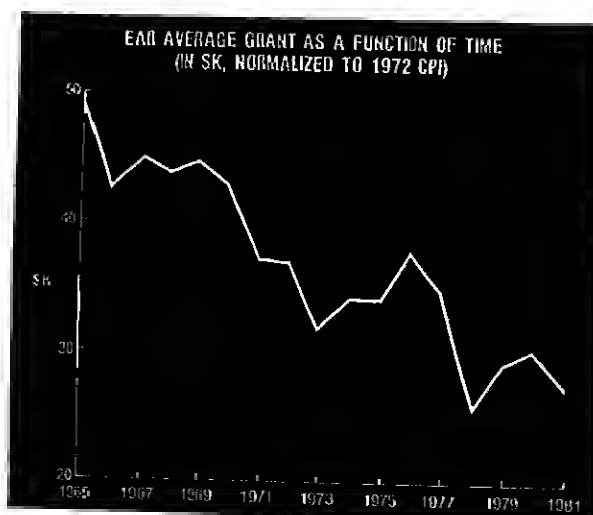


Fig. 1. Plot of the average annual grant made by the Earth Sciences Division (EAR) of the National Science Foundation as a function of time (in \$K normalized to 1972 CPI).

HEAO-2 Completes Flight Mission

The second High-Energy Astronomy Observatory (HEAO 2) has expended its control gas supply, completing its flight mission.

The spacecraft was launched Nov. 13, 1978. It carried the world's largest focusing X-ray telescope and an array of imaging and analyzing astronomy instruments. During its extra-long lifetime, it performed thousands of studies of X-ray-emitting stars, supernova remnants, galaxies, and quasars.

HEAO 2 is one of a family of three highly successful scientific satellites managed by NASA's Marshall Space Flight Center, Huntsville, Ala. With 2 years and 5 months of operation, HEAO 2, like its predecessor HEAO 1, performed more than twice as long as its design called for—a feat expected to be equaled by the third observatory, which is still in operation.

Although it will take years for participating astronomers to analyze completely all the data they received, important data have already been obtained about the X-ray output of normal stars, the composition of supernova remnants, the distribution of mass in galaxies and clusters of galaxies, and the origin of the extragalactic X-ray background.

The spacecraft was operating extremely well, Marshall Center officials reported, when it expended the last of its reaction control gas Saturday afternoon, April 25, and could no longer maintain its pointing attitude. Spacecraft and instrument engineering tests were performed until the batteries were discharged, and on a subsequent orbit Sunday morning, when the solar panels were receiving sunlight, all systems were powered down. Reentry and burnup are expected to take place next year.—PMB [Source: NASA] ☐

Petroleum Research Grants

Five earth sciences grants are available through the American Chemical Society's Petroleum Research Fund (PRF). These grants are intended to assist advanced scientific education and fundamental research in the petroleum field, which may include any field of pure science which may afford a basis for subsequent research directly connected with the petroleum field, according to Justin W. Collet, PRF program administrator.

The grants are divided into three categories. Collet said. The first, called type A, generally supports graduate students or postdoctoral fellows. Awards may be up to \$15,000 per year for a maximum of 3 years. The second, type B, is for faculty research with undergraduate students in academic departments which do not offer a Ph.D. degree. The maximum award is \$5000 annually for 2 years. And last, a special "starter" grant program is available for beginning faculty investigators. These grants consist of

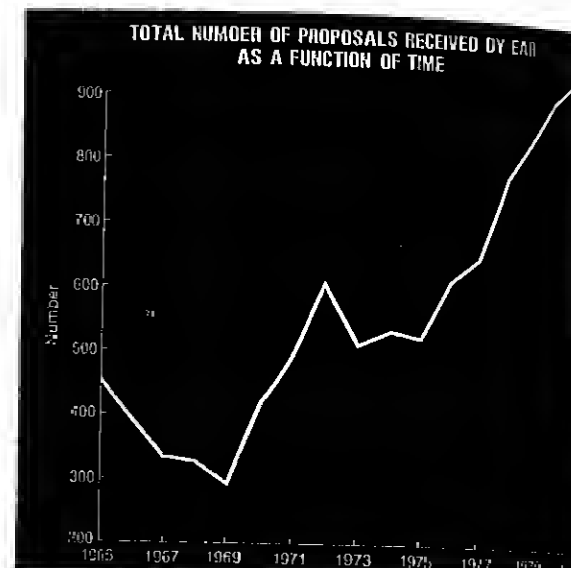


Fig. 2. Total number of proposals received by the Earth Sciences Division (EAR) of the National Science Foundation as a function of time.

during the past decade or so, Bratt said. In 1980 the average grant was close to \$50,000.00 in the earth sciences. (See Figure 1.) In 1981 the average annual grant is about \$27,000.00. Inflation has caused the decrease, while the ratio of the budgeted dollar per investigator has remained less than level, and while the cost of research has increased. Instrumentation is not cheap: one modern mass spectrometer laboratory costs \$400,000.00, enough to equip ten earth science departments thirty years ago!

At the same time, the portions of grants allocated to be spent on investigator's salaries and institutional overhead have increased.

A major problem at the NSF Earth Sciences Division today is the enormous number of research proposals. It is an almost impossible task to process the proposals, much less fund them. The NSF viator today will see 10–15 stacks of proposals being moved about, warehouse style, by forklift trucks. A current joke at the NSF is that assistant program managers are being hired just to enable the divisions to hire secretaries to handle the load of proposals. Congress has repeatedly cut the staff and operation of NSF, but the work load continues to increase. The number of proposals received by the NSF Earth Sciences Division is increasing by an exponential function (see Figure 2)—PMB

\$10,000 for 2 years, Collet said, and are limited to faculty members in the first 3 years of their first faculty appointment. These faculty members cannot have any major support of their research, except for that provided by their institution.

Proposals, accepted throughout the year, are evaluated by the 24-member PRF Advisory Board. For additional information, contact Collet, The Petroleum Research Fund, American Chemical Society, 1155 16th Street, N.W., Washington, D.C. 20035 (telephone: 202-872-4481).—BTR ☐

Geophysical Event

Pagan Volcano, Mariana Islands, Western Pacific Ocean (18.13°N, 145.80°E). All times are local (GMT + 10 h). A strong explosive eruption from North Pagan, the larger of the two stratovolcanoes that form the Pagan volcano complex, began on May 15. While reporting strong felt seismicity on the island, radio operator Pedro Castro suddenly announced at 0915 that the volcano was erupting. Communication was then cut off. An infrared image returned from the Japanese geostationary weather satellite at 1000 showed a very bright circular cloud about 80 km in diameter over the volcano. The cloud spread SE at about 70 km/h, and by 1800 its maximum height was estimated at 13.5 km from the satellite imagery. Waikening of activity was evident on the island returned at 1900, and on the next image, at 2200, feeding of the eruption cloud had stopped, with the plume and all of the cloud located about 120 km SE of the volcano. No additional activity has been detected on the satellite images, but by 0400 the next morning, remnants of the plume had reached 10°N and 155°E.

Aircraft attempting to land on Pagan Island were prevented from doing so by the eruption. At 1235, pilots reported a mushroom cloud over the island and ashfall over the island and eastern area. Ash falls were also reported from Agrigan Island, 105 km to the NW. Additional plume at 1410 indicated that the eruption was intense. The cloud had reached more than 7-km altitude. Press International reports that aircraft crews flying over the island at two different (but unspecified) times saw to 10.5 and 18 km. The U.S. Navy reported, "A plume down the SW flank to within 1 km of the island's edge, 1/2 km of the airstrip. However, the aircraft instrument measured surface temperature of the lava at 200°C." The Japanese merchant ship *Hoya Maru* reported persons on Pagan Island early May 16. None of the islanders were injured.

The U.S. Geological Survey sent a three-man team to the Hawaiian Islands to observe the eruption. They had been on the island since May 15. The report

Information contacts: Frank Smigalski, NOAA/National Environmental Satellite Service, Synoptic Analysis Branch, S/OP33, Camp Springs, Maryland 20733.

Gus Telegadas, Room 617, NOAA/Air Resources Laboratory, Silver Spring, Maryland 20910. Robert Tilling, U.S. Geological Survey, Stop 906, National Center, Reston, Virginia 22092. U.S. Department of Defense. United Press International. ☐

Geophysicists

Daniel P. Beard was appointed executive director of the Renewable Natural Resources Foundation, effective May 1. He succeeds Gordon Fredline, who has retired.

Farouk El-Baz, of the Smithsonian's National Air and Space Museum, was presented with the Arab Republic of Egypt Order of Merit—First Class by President Anwar Sadat. El-Baz, cited for his contributions to space geology, advised Sadat on scientific matters. The presentation was made at the First Science Celebration Day in Cairo, on April 14.



James F. Hays will succeed Raymond Siever as chairman of the Department of Geological Sciences at Harvard University as of July 1. Siever will remain on the department's faculty.

Felix J. Schneider has been appointed a vice president at Gershty & Miller, Inc., consulting groundwater geologists and hydrologists. He is the director of the company's Tampa, Fla., and Baton Rouge, La., offices.

New Publications

Early Diagenesis, A Theoretical Approach

R.A. Berner, Princeton Ser. in Geochem., Princeton University Press, Princeton, New Jersey. xii + 241 pp., 1980, \$25 (cloth), \$9.50 (paper).

Reviewed by Donald L. Graf

In the last 15 years the author has carried out field and laboratory studies of solid importance to an impressive variety of areas in sedimentary geochemistry. This activity, coupled with his lively curiosity about established theoretical concepts in other sciences that can be brought to bear on geochemical problems, has yielded numerous scientific articles and an earlier book, in 1971. We encounter most of the theoretical aspects of these publications again here, leavened with additional calculations, more recent literature citations, and additional insights about applicability obtained during the intervening years of teaching and research.

The transport equations that form the theoretical core of the book should be familiar to chemical engineers, hydrologists, petroleum reservoir engineers, and physical oceanographers. Most of the applications are to ocean sediments. The book is divided into a theoretical section, in which suitable equations are developed to describe the physical, biological, and chemical processes encountered in diagenesis, and a discussion of applications to marine sediments of the continental margins, deep-sea sediments, and nonmarine sediments. However, because much of the literature cited in the latter section involves tests of mathematical models, the book is in practice an interplay throughout between equations and sets of data, with interspersed excerpts from peripheral fields (e.g., equilibrium thermodynamics, ion exchange, rate laws, microbial reactions, nucleation, and crystal growth).

Even though some useful mathematical simplifications result from considering only the first few hundred meters of sediment, the problems considered are still very complex. The common-sense approach used by Berner and his fellow modelers is first to define theoretical relationships with reasonable but not ultimate precision, then to seek plausible ways of simplifying these expressions for particular problems, next to accumulate a number of tests of the simplified expressions against particular sets of data, and then to fine-tune back and forth until models are obtained that, we hope, are uniquely successful in describing a particular geochemical environment.

The book is a veritable encyclopedia of simplifying assumptions (11 are cited in developing one model for calcium carbonate distribution on the floor of the deep ocean), which raises problems in comparing results from different workers with slightly different notions of optimum simplification. The facility with which physical units are redefined is a little unsettling, e.g., because bioturbation is sometimes lumped within the diffusion term in modeling, it emerges (p. 31) as a category of diffusion. Dispersion is another category (p. 31), which should interest hydrologists, who have made molecular diffusion into chemical dispersion. A blessing of complex natural systems is that they afford

glets and hydrologists. He is the director of the company's Tampa, Fla., and Baton Rouge, La., offices.



Kenneth M. Watson was appointed director of the Marine Physical Laboratory at Scripps Institution of Oceanography. He comes to Scripps after serving for more than 20 years as a professor of physics and research at the University of California at Berkeley and at the Lawrence Berkeley Laboratory. Watson succeeds Fred N. Speiser, who now heads the University of California's Institute of Marine Resources. (Photo courtesy of Scripps)

Geophysicist Obituaries

The following AGU members are recently deceased: Joseph M. Caldwell, 69, on December 21, 1980. Joined in 1942.

William M. Chappin, 46, on February 18, 1981. Joined in 1944.

James E. Gill, 80, in January, 1981. Life member, joined in 1947.

James G. Gilly, 84, on December 31, 1980. Life Fellow, joined in 1934.

Nathan M. Newmark, 70, on January 25, 1981. Fellow, joined in 1962.

Anthony J. Polos, 71, in June, 1980. Life member, joined in 1942.

Ernest Tillotson, 77, on March 29, 1981. Life member, joined in 1947.

Georg D. Whitmore, 82, on February 9, 1981. Life member, joined in 1948.

Famous Last Words:



Which one ???

- Was it the "special" JGR issue on Saturn?
- Or the Radio Science papers on Optical Communications?
- The papers on SAR Imaging of Ocean Waves?
- The Evolution of the Atmospheric Ozone?
- Ocean Intratropical Earthquakes?

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1. User needs: In four papers are discussed the remote sensing of ice clouds, lidar visibility measurements, and several applications. Here, no contribution has been made from oceanography and astronomy.
2. Particle descriptions: Five papers describe exhaustively the shape of reindrops and ice crystals, and of aerosols from various regions. Here, again, the subject should have been extended to the other fields of applications, oceanography, and astronomy.

3. Theoretical methods: Fourteen papers discuss various ways to compute the scattering by particles of various shapes. All contributions cover the subject in great depth, allowing the reader to gain an overview.

4. Experimental methods: Ten papers were presented during this session. In several of them, microwave analog experiments are described, where the extinction of single "analog" particles is directly measured. The methodology of in situ measurements (i.e., measurements of the extinction properties of a volume of air) has not changed, but the technology has improved considerably. Almost all authors recommended without detailed discussion that measurements be made of as many components of the scattering matrix as possible. This chapter alone deals with the scattering by biological particles.

5. Inversion and information content: Only two papers were devoted to this subject, since even for simpler problems of scattering by pure spherical particles it is yet relatively unexplored. In one paper the size of the scatterer is inferred from polarization measurements, an attractive tool which is seldom used. In the other paper a comparison is made between irregularly shaped and spherical particles, using laser and direct solar radiation measurements. The conclusion is that nonspherical particles in the atmosphere may be considered as equivalent spheres without serious error.

Although many abstracts are rather short and contain only limited information, this book can be considered as an extremely helpful tool for all those research groups and individuals who are engaged in remote sensing of particle properties and quantities, either when the particles are imbedded in another medium (gases or water) or entirely free in deep space. I recommend open publication of such proceedings, because it allows the worldwide community to participate in discussions of extreme importance to their research. Expected future restrictions on travel funds will even force such means of scientific communications. A paperback version would seem adequate and less expensive than this book.

The organizers of this meeting should be encouraged to attempt another one, but it should include a much wider field of scientific research and broader international participation than they could assemble at this workshop.

E. Reschke is with the Institut für Geophysik und Meteorologie, University of Cologne, Köln, West Germany.

Light Scattering by Irregularly Shaped Particles

D. W. Schuerman (Ed.), Plenum, New York, x + 334 pp., 1980, \$39.50.

Reviewed by E. Reschke

This book contains the text of two introductory papers and extended abstracts of 35 contributed papers which were presented during the International Workshop on Light Scattering by Irregularly Shaped Particles (June 6–7, 1979, State University of New York at Albany, New York). The purpose of this workshop was to review the state of understanding and the modeling of the scattering of electromagnetic radiation by irregularly shaped particles and to compare it with the first-order solutions which usually are based on equivalent spherical particles.

The field of application is extremely wide. It reaches from interpretations of stellar atmospheres, interplanetary dust, and atmospheric aerosols to the observation of plankton and other suspended materials in the oceans with remote sensing methods.

The papers of this workshop did not cover all subjects. In the introduction, D. Deirmendjian, a meteorologist, favored the empirical approach (i.e., in situ measurements and adjustments to equivalent particles). J. M. Greenberg, however, recommended extensive basic research of the physical processes involved in scattering of light by irregularly shaped particles; thus, the particle shape must be known and remote sensing techniques should use all means to exploit the information content carried by the scattered light. The other 35 papers have been gathered into 8 subgroups.

Item B. Rossow, Peter H. Roth, Jacob Rubin, David Rusch, Sidney L. Russak.

Relati Sanchez, Kim David Saunders, Samuel M. Savin, David W. Sexton, Marc L. Sber, Kenneth F. Scheldegger, John William Schlus, Ulrich Schmidt, Robert W. Schunk, David Seidemann, Stephen Self, Margaret Ann Shea, Gordon G. Shephard, Peter N. Shive, Loren Shura, John M. Sinton, George L. Sisco, Charles W. Slaughter, David B. Slemmons, Don F. Smart, Douglas L. Smith, Eugene I. Smith, Scott B. Smithson, Charlaa P. Sonett, Frank Spere, R. R. Steeves, Daniel B. Stephens, J. Carl Stepp, Robert G. Stone, William D. Stuart, Dealee E. Stuart-Alexander,

Meetings

Applied Glaciology Symposium

The International Glaciology Society has stated its second meeting on the applied aspects of snow and ice research for August 23-27, 1982, at the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. This Second Symposium on Applied Glaciology will include technical sessions on the engineering problems of floating ice; engineering problems of ground ice; icebergs and glaciers; properties and behavior of snow and ice; snow removal and control; avalanche control and snow pressure; ice accretion; and modeling techniques in applied glaciology.

For additional information, contact the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom. ☐

Coastal Engineering Conference

The 18th International Conference on Coastal Engineering will be held November 14-19, 1982, in Cape Town, Republic of South Africa.

Topics to be covered at the conference include wind current and wave action; tides and long waves; sedimentary processes and coastal morphology; estuary and inlet behavior; coastal structures and recreational facilities; ship motions and harbor entrance design; ocean outfall design and construction; and environmental aspects of coastal engineering.

Five copies of a synopsis (not to exceed two pages) of papers proposed for the conference should be sent to Billy L. Edga, Secretary, Coastal Engineering Research Council, Department of Civil Engineering, Clemson University, Clemson, SC 29631. Deadline is October 31, 1981. ☐

Underwater Mining Institute

The 12th Underwater Mining Institute is scheduled for October 20-22 in Madison, Wisconsin. The program will include presentations on mineralogy of marine sulfide deposits; tectonic setting for spreading center sulfide deposits; seafloor sulfides in the Gesteiras and other Pacific crests; new developments in offshore Ase offshore in operations; geophysical techniques for finding underwater copper nodules; new geochemical techniques for marine minerals exploration; changes in the international mining trade of relevance to marine mining; and the impact of sea grant mineral research on industry. The program will also include tours to local research laboratories.

For registration information, contact Gregory Hedden, Sea Grant Advisory Services, University of Wisconsin, 1815 University Avenue, Madison, WI 53708 (telephone: 608/262-0844).

For technical program information, contact J. Robert Moore, Marine Science Institute, University of Texas, P.O. Box 7999, University Station, Austin, TX 78712 (telephone: 512/471-4816). ☐

AGU Midwest Meeting

September 17-18
Minneapolis, Minnesota

Abstract Deadline: July 1
Convenor: V. Rama Murthy

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Marine structure and dynamics. Contact Geoffrey Davies or Clem Chase.

Rock water interactions: Hydrothermal processes and metagenesis. Contact William Seyfried.

Precambrian crustal evolution of the North American continent. Contact Paul Walblen.

Geomagnetism and paleomagnetism. Contact Subir Banerjee.

Hydrology in the mid-continent U.S. Contact H. O. Plannkuch or E. C. Alexander, Jr.

Abstracts

Use standard AGU format (see page 20 of January 13 EOS) and send original and two copies of abstracts to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in EOS with a substantive meeting report after the meeting. There will be no abstract charge.

Peter Styias, Steven T. Sues, Randall L. Svendsen, Predasp Talwani, Michael A. Tamerin, Tai-leng Teng, H. R. Thierstein, Ronald J. Thomas, T. R. Topozada, Donald L. Turcotte, Petr Vanicek, Kenneth L. Verosub, Thomas A. Vogel, Elisavlos G. Vornvoris, Carl A. Von Hake, William B. Wadsworth, Harve S. Wall, Mary Emma Wagner, Clyde Wahrhaftig, Raymond J. Walker, C. Wang, Steve Wagener, Ray F. Wales, J. E. White, John M. Wilcox, James G. Williams, John Wilson, W. P. Winn, I. J. Won, David D. Woodbridge, Francis T. Wu, Shi Tsen Wu, Klaus Wyrki, Gour-Teyh Yeh, Hsueh-Wen C. Yeh.

Aquifer Protection Policies

A special program entitled 'Effects of New Aquifer Protection Regulations and Policies on Ground Water Management' will be held at the American Society of Civil Engineers' Spring Convention and Exhibit during the week of April 19, 1982, in Las Vegas, Nevada. The program is sponsored by the Hydraulic Division's Committee on Ground Water Hydrology and by the Environmental Engineering Division's Committee on Hazardous Waste Management.

A call for papers has been issued for the following topics: review of regulatory activity, future protection regulations, and policies; groundwater quality monitoring; design of well networks; groundwater studies stemming from regulations, including remedial measures; and ongoing and needed research. Research topics should address pollution sources, transport and fate of pollutants, methods of detection, and aquifer rehabilitation.

Geophysicists interested in presenting a paper should send a one-page abstract to Richard J. Schicht, Illinois State Water Survey, 605 East Springfield Avenue, P.O. Box 5050, Station A, Champaign, IL 61820 (telephone: 217/333-2594). Deadline is July 31. ☐

Workshop on Remote Measurement of Underwater Parameters

This workshop was held at Bolkasjø, Norway, October 30 to November 1, 1980. It was arranged by the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division; Institute of Geophysical Research, University of Bergen; and Office of Naval Research, Arlington, Virginia. It was sponsored by the Royal Norwegian Council for Scientific and Industrial Research, the North Atlantic Treaty Organization, and the Office of Naval Research.

One may conclude from the meeting that the idea that it may be possible to determine any subsurface variables of the ocean by remote sensing is attractive in principle, but realizable now, in a severely limited manner, and still possible of advancement. Sound waves are now used for tracking SOFAR floats to map out deep and mid-level currents, and acoustic tomography offers possibilities that are now being explored in the field, with the first tentative results now being reported. Acoustic tomography measures a combination of velocity and sound speed fields over the water column, and the data can be interpreted to give mean variables and a number of integral measures of water properties as well as statistical measures of the field of variables. The upper mixed layer is not so well sampled by acoustic tomography, so for the upper layer, one will have to rely upon other methods. In saltwater, electromagnetic waves cannot be used profitably; for brackish or fresh water overlying salt water, radar monopulse methods offer some promise. Such methods are in routine use for ice profiling on lakes and rivers, and extension to estuaries may prove useful and practical.

Satellite interrogation of drifters, and shore station tracking of drifting buoys are other methods of obtaining information about the ocean without having to go there each time one wants information.

Among the active methods of sensing variables in the upper ocean are ground wave and ionospheric scatter radar. The ground wave radar method, one example of which is CODAR, when used from shore, can sense the current field in the upper 12 meter of the ocean with a spatial resolution of 1.5 km² and 0.10 m/s. While a few examples were given of synthetic aperture radar (SAR) signatures in SEASAT-SAR data, the processing algorithm was not described in sufficient detail to enable one to make any judgment about the method, although in principle it should be possible to infer current along one direction from Doppler-shifted reflections. The SAR data also show a strong correlation between bathymetry and sea surface roughness. As past workshops where these data have been presented, there was little, if any, analysis given of the dynamics of the processes. The active optical methods, using laser light sources, take advantage of the following effects: the Rayleigh scattering broadens the spectral width, and the broadening is temperature dependent. Thus, one may be able to measure temperatures by observing the reflected light from pulsed, range-gated lasers.

Next comes Raman backscatter for measurements of salinity, temperature, and other variables, and then comes Brillouin scattering to sense sound velocity. When a very intense laser signal hits the water, it will also heat it and generate an acoustic signal. The reflection of the acoustic signal back to the surface (by density structures) will in turn generate a measurable surface signature. One can use this for depth sounding from airplanes and, ultimately, from even more remote platforms. The combination of possibilities, although few of them are now at a stage ready for routine practical use, suggests that one should follow developments closely. The methods, so far, seem to be mainly useful in the upper 50 m of the ocean but may some day be extended to several times that depth. This will tell us very little about the deeper water column. But the possibility of obtaining synoptic data, even in this upper few meters, seems interesting. The technology needs to be worked out, and the oceanographic community need not yet hold its collective breath and sit around and wait, but the new methods may be upon us in a few years. The active and passive remote sensing of water properties has, of course, also been extended to sensing of biological properties. Here the workshop contained a very interesting set of papers on algorithms and the inverse problem and an example of application of color measurement to mud flat and tidal flat properties.

The first paper was by N. K. Hojerslev, who showed that different regions of the ocean have sufficiently different plankton-related color that a universal algorithm for interpreting color in terms of biological measures will have serious shortcomings. The next paper, by J. Fischer and H. Graef, who had examined the problem of remote sensing of particulates, found that the problem of determining particulate matter variables from color observations was not well conditioned and that the matrix really had only two linearly independent characteristic vectors. The tentative conclusion of this listener to these two papers was that before one can use color to determine biological variables, one needs to introduce some information about local biological properties as a constraint on the inversion process. This means that one needs biologists to help with the interpretation; one cannot find a way where the technology system and the computer can do it all by themselves. This should not be a source of wonder because biology is a nontrivial branch of science and cannot be left to automation. One has to develop a certain judgement and expertise before one can produce useful results.

The Coastal Zon Color Scanner provides useful information for biologists, but the information from the intensity of color bands cannot be used blindly, it has to be interpreted through the use of knowledge about local biology as a constraint on the inversion process. An example of how to incorporate local knowledge in an inversion problem was given by Prober, Bahr, and Dennert-Mueller, who interpreted the LANDSAT images from different channels, in terms of tidal flat classes, including dry sand, wet mud, and others by using 'training fields' and in situ establishment of field characteristics. The use of these training fields introduced the local constraint on the inversion process and made it possible to classify a large region from LANDSAT data at a field work in a limited area that covered the important classes of flats.

This is apparently the direction in which one has to seek methods for interpreting upper ocean color. Also, no doubt, the same method can be used with active sensors, where one senses the color quality of reflection of laser lights from different depths, including fluorescence effects.

While some of the methods seemed kind of far from practical realization in the near future, there is rapid technology development under way.

The workshop was informative for the participants, and the other assessments provided by the working groups showed that one cannot dismiss remote sensing techniques out of hand, that the technologies need to encounter scientists to learn what one should look for, and it showed how one may adjoin specialist knowledge to remote sensing data. In this sense the workshop was educational, resiliant, and productive of sober evaluations of methods. An abstract volume will be available shortly from the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division, P.O. Box 309, Blindern, Gaustadallen 30 D, Oslo, 3, Norway.

This meeting report was prepared and submitted by Erik Møller-Christensen of the Department of Meteorology and Physical Oceanography at MIT, Cambridge. ☐

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Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

May 27-29 Canadian Meteorological and Oceanographic Society 15th Annual Congress, Saskatoon, Saskatchewan, Canada. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Outleth Street, Downsview, Ontario M3H 5T4 Canada.)

June 1-4 First JECSS Workshop Tokyo, Japan. Sponsor, Tsukuba University. (T. Kashiishi, Dept. of Oceanography, Texas A&M University, College Station, TX 77843.)

June 1-5 Second International Symposium on Tidal Technology for Surveying and Geodesy, Banff, Canada. Sponsors, AGU, Canadian Institute of Surveying, Univ. of Calgary. (Klaus-Peter Schwarz, ISS Symposium 1981, Division of Surveying Engineering, Univ. of Calgary, Calgary, Alberta T2N 1N4 Canada.)

June 3-4 Symposium on the Ecology and Management of Reservoirs, Université Laval, Québec, Canada. Sponsors, UNESCO, Université du Québec, Université Laval, Hydro-Québec, Société d'Énergie de la Baie James. (P. G. C. Campbell, Université Québec, INRS-Eau, C.P. 7500, St. Foy, Québec G1V 4C7 Canada.)

June 4-5 Eastern Snow Conference, Syracuse, N.Y. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 7-11 Eighth Ocean Energy Conference for the Department of Energy, Washington, D.C. Sponsor, Marine Technology Society. (Harry Irwin, Marine Technology Society, 1730 M St., N.W., Washington, DC 20036.)

June 10-14 International Geoscience and Remote Sensing Symposium, Washington D.C. Sponsors, AGU, IEEE Geoscience and Remote Sensing Society. (F. T. Uhlir, Remote Sensing Laboratory, Univ. of Kansas Center for Research, Inc., West Campus, Lawrence, KS 66045.)

June 14-19 Second International Conference on Urban Storm Drainage, Urbana, IL. Sponsors, Univ. of Illinois, International Union in Urban Storm Drainage, International Association of Hydraulic Research, International Association of Water Pollution Research, American Society of Civil Engineers. (B. C. Yan, Department of Civil Engineering, Univ. of Illinois, Urbana, IL 61801.)

June 15-19 International IEEE/APS Symposium, National Radio Science Meeting, and International IEEE/MTS Symposium, Los Angeles, Calif. (Prof. N. G. Alexopoulos, 7732 Boulder Hall, Department of Electrical Sciences, Univ. of California, Los Angeles, CA 90024.)

June 22-28 International Symposium on Erosion and Sediment Transport Measurement, Florence, Italy. Sponsors, IAHS, International Commission on Continental Erosion, National Research Council of Italy. (P. Teccol, Secretary of the Organizing Committee, Istituto di Ingegneria Civile Via S. Maria, 3 50139 Firenze, Italy.)

June 23-28 Seventh International Symposium on the Machine Processing of Remotely-Sensed Data, West Lafayette, Ind. Sponsor, Laboratory for Applications of Remote Sensing, Purdue Univ. (D. B. Morrison, Purdue Univ./IARS, 1220 Potter Cr., West Lafayette, IN 47906.)

June 24-28 International Symposium on Real-Time Operation of Hydrosystems, Waterloo, Ontario, Canada. Sponsor, Water Resources Group, Univ. of Waterloo. (T. E. Unny or E. A. McBean, Univ. of Waterloo, Department of Civil Engineering, Waterloo, Ontario N2L 3G1 Canada.)

June 29-July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology. (Barbara Dullien, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.)

June 29-July 3 Conference/Workshop on Heterogeneous Catalysis—Its Importance to Atmospheric Chemistry, Albany, N.Y. Sponsors, NSF, NASA. (V. A. Mohan, Atmospheric Sciences Research Center, State Univ. of New York, Albany, NY 12222.)

June 29-July 11 Seminar on Fluid-Dynamical Problems in Astrophysics and Geophysics, Chicago, Ill. Sponsors, American Mathematical Society, Society for Industrial and Applied Mathematics. (Meeting Arrangements Department, American Mathematical Society, Post Office Box 6248, Providence, R.I.)

July 8-11 Geographers '81-South African Geodynamics Project and 3rd International Plinius Symposium, Pretoria, South Africa. Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat B. 217, CSIR, P.O. Box 395, Pretoria 0001 Republic of South Africa.)

July 8-10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsor, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 15-17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Buchanan, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21-23 Chapman Conference on Spatial Variability in Hydrologic Modeling, Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

July 21-30 21st General Assembly of IA-SPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27-30 Eighth International Symposium on Urban Hydrology, Hydrodynamics, and Sediment Control, Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 208B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug. 3-15 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug. 4-7 International Conference on Energy Education, Providence, R.I. Donald K. Iwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9-15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, IAGLR, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 9-18 International Congress of Surveyors, F.I.G., Montreux, Switzerland. Sponsor, Fédération Internationale des Géomètres. (American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 10-14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10-14 Water Forum '81: Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage. (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22044.)

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Aug. 17-22 Ninth International Symposium on Earth Tides, New York, N.Y. Sponsors, IAG, IUGG, Columbia Univ. (J. T. Kuo, 828 S.W. Mudd, Columbia Univ., New York, NY 10027.)

Aug. 18-21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Hsigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5081.)

Aug. 20-21 Second International Symposium on Computer-Aided Seismic Analysis and Interpretation, North Dartmouth, Mass. Sponsors, Electrical Engineering Department, Northeastern Massachusetts University, IEEE Computer Society, IEEE Acoustics, Speech and Signal Processing Society. (C. H. Chan, Electrical Engineering Department, Northeastern Massachusetts University, North Dartmouth, MA 02747.)

Aug. 24-28 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodetic Institute. (C. C. Tscherning, International Symposium Management, Geodætisk Afdeling, Geodætisk Institut, Garmshave Allé 22, Charlottenlund DK-2820 Denmark.)

Aug. 24-29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (C. E. Lund, Institute of Solidifying Committee, Uppsala University, Box 566, 22 Uppsala, Sweden.)

Aug. 28-Sept. 9 '81 Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan, IAVCEI. (Daisuke

Shimozuru, IAVCEI Symposium on Arc Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31-Sept. 2 Third International Colloquium on Mars, Pasadena, Calif. Sponsors, NASA, Lunar and Planetary Institute, Division of Planetary Sciences of the AAS. (Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109.)

Aug. 31-Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marzellplatz 8, D-8000 München 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairman of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c/o LAIEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7-12 Third International Symposium on Antarctic Geology, Columbia, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society. (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 8-12 American Society of Photogrammetry-American Congress on Surveying and Mapping Fall Convention, San Francisco, Calif. (L. W. Aggers, USGS, 345 Middlefield Road, M/S Stop 31, Menlo Park, CA 94025.)

Sept. 13-17 National Water Wall Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43005.)

Sept. 18-18 Oceans '81, Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering, AGU. (R. Negle, Publicity Manager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 17-18 Midwest Meeting, Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept. 17-18 Pacific Northwest Regional Meeting, Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 98920.)

Sept. 20-22 National Water Wall Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43005.)

Sept. 28-Oct. 10 NATO Advanced Study Institute on Chemistry of the Unpolluted and Polluted Troposphere, Corfu, Greece. (W. Jaeschke, Center of Environmental Protection, University of Frankfurt, Robert-Meyer-Str. 11, 6000 Frankfurt/Main, FRG.)

Oct. 6-8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario, Canada. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. B. Sheerawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 11-14 Coastal Society's Seventh Annual Conference, Galveston, Tex. (N. West, Coastal Society Conference, Department of Geography and Marine Affairs, Univ. of Rhode Island, Kingston, RI 02881.)

Oct. 11-15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 445, La Brea, CA 90031.)

Oct. 13-15 Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, La. Sponsors, Louisiana Geological Survey, Department of Natural Resources, Energy Programs Office, Louisiana State University; U.S. Department of Energy. (Ann Bachman, Conference Coordinator, Energy Programs Office, 105 Hill Memorial, Louisiana State Univ., Baton Rouge, LA 70803.)

Oct. 13-18 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hephka, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14-18 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 833 5th Ave., S.W., Calgary, Alberta, Canada T2P 2Y6.)

Oct. 22-24 Fourth Conference on the Physics of the Ion and Saturnian Magnetospheres, Laurel, Md. Sponsor, NASA. (S. M. Krimigis, Applied Physics Laboratory, Johns Hopkins Univ., Laurel, MD 20810.)

Oct. 26-30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shorelines Commission of the International Union for Quaternary Research, Scientific Committee of the World Commission of Underwater Activities. (Patricia M. Masters, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

November 1-5 Sixth Biennial International Estuarine Research Conference, Glendon Beach, Oreg. Sponsor, Estuarine Research Federation. (Joy F. Watson, Treasurer, USFWS Suite 1952, 500 N.E. Multnomah Street, Portland, OR 97232.)

Nov. 2-8 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Amos Research Center, Moffett Field, CA 94035.)

Nov. 9-11 Special Conference on the Mechanical Behavior of Soil, University Park, Pa. Sponsor, Rock Mechanics Laboratory, Department of Mineral Engineering, Pennsylvania State University. (H. Reginald Haidy, J. Rock Mechanics Laboratory, Room 117, Mineral Sciences Building, Pennsylvania State University, University Park, PA 16802.)

Nov. 9-20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAG, IUGG Local Committee of Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography. (R. Ormari, Survey of Kenya, P.O. Box 30045, Nairobi, Kenya.)

Nov. 30-Dec. 11 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM, Research Division, Box 218, Yorktown Heights, NY 10598; or G. S. Watson, Bernoulli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08544.)

Dec. 3-5 Topical Conference on the Processes of Planetary Rifting, San Francisco, Calif. Sponsor, Lunar and Planetary Institute. (Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Dec. 7-11 AGU Fall Meeting, San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 18-19 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluva, Istituto di Petrografia, Via Gramsci 9, 43100 Parma, Italy.)

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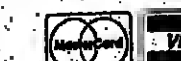
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Postdoctoral Research Associate Position. The Johns Hopkins University, Applied Physics Laboratory, is seeking a Postdoctoral Research Associate for studies of magnetospheric-ionospheric coupling, hydromagnetic waves, and plasma instabilities in the ionosphere and magnetosphere. The selected candidate will participate in the analysis and interpretation of data from spacecraft and ground-based radars as well as in the development and implementation of new ground-based and spacecraft studies. Positions are for one year and are renewable. Tenure may begin at any time through September 1, 1981. Applications should be addressed to Mr. Steven F. Soja, Dept. ACH-15, The Johns Hopkins University, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20820.
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Minerology and Petrology. Applications are invited for a faculty position at Weber State College, effective September 1981. This is a permanent faculty position with rank, salary, and tenure track status determined by qualifications. Responsibilities include teaching undergraduate courses in mineralogy, petrology, and geochemistry and some combination of mineral deposits, structural geology and introductory geology. Ph.D. preferred. WSC is a large (10,000 students) undergraduate college with a strong geology program graduating about 10-15 majors per year. The college is situated in northern Utah at the boundary between the Rocky Mountain and Great Basin provinces and adjacent to the Overthrust Belt. The Department is well equipped for field-oriented teaching and research. The closing date for applications is July 1, 1981. Applications, including evidence of teaching proficiency and the names of three references should be sent to S. R. Ash, Chairman, Department of Geology/Geography, Weber State College, 3760 Harrison Blvd., Ogden, Utah 84403.
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It is anticipated that proposing institutions will negotiate with one or more applicants to become a part of their proposal, and selection will be based, in part, on the qualifications of the successful applicant who will become an employee of the host institution. Required qualifications include experience in oceanographic research and knowledge of research ship operations. Salary is negotiable depending on professional qualifications. Deadline for applications is July 31, 1981.

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Physical Oceanographer/Materials University of Newfoundland. Memorial University of Newfoundland in St. John's seeks to fill two faculty positions in physical oceanography. One position is in ocean dynamics and the other is in theoretical oceanography. Interest and experience in carrying out field programs is desirable. Candidates for both positions should hold a Ph.D. in physical oceanography, or a closely related field (e.g., fluid mechanics). The program in physical oceanography at Memorial University is new and offers the successful applicant an opportunity to participate in the development of this field in a frontier area. Memorial University is located in St. John's, Newfoundland, which is rapidly becoming a centre of ocean studies related to fisheries and offshore hydrocarbon development in Eastern Canada.

Salary will be commensurate with experience and qualifications. Applications, including curriculum vitae and the names of three referees, are to be submitted to: Dr. C. W. Cho, Head, Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X7.

Faculty Position/University of Alaska, Fairbanks. Applications are invited for a tenure track position in economic geology in the Geology-Geophysics Program to teach undergraduate and graduate courses in ore deposits, mineralogy, and exploration geology. Applicants should have demonstrated practical experience in mineral exploration, regional and detailed geologic mapping as well as a commitment to research in the general area of ore deposits. The candidate will be expected to pursue a vigorous graduate teaching and research program in economic geology with students primarily oriented toward careers in the mineral industry.

Preference will be given to individuals with experience in and/or subterranean mineral research and a record of close collaboration with the mineral industry. Academic rank and salary commensurate with experience. Ph.D. required. Send resume and three letters of reference to: Dr. Robert L. Finkbeiner, Department of Geology, University of Alaska, Fairbanks, Alaska 99707. Applications will be accepted until June 30, 1981, or until filled. The University of Alaska is an equal opportunity/affirmative action employer.

Sedimentologist-Sedimentary Petrologist/Ohio State University. The department of Geology and Mineralogy invites applications for a tenure track faculty position in sedimentology and sedimentary petrology. The appointment is available from August 1981.

Salary and rank competitive and commensurate with experience. Applicants should send resumes and names of at least three referees or address inquiries for further information to Peter N. Webb, Dept. of Geology and Mineralogy, The Ohio State University, 125 South Oval Mall, Columbus, Ohio 43210. Closing date is July 1, 1981.

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Seismology. Research associate position anticipated (September 1, 1981), telemetry monitoring project in Virginia. Problems focus on seismicity and neotectonics in the state. Peter M. S. geophysicist with thesis in observational seismology, but others considered. Applications, transcripts and two letters of recommendation to: Dr. O. A. Bollinger, Seismological Observatory, VPI&SU, Blacksburg, Virginia 24061. Deadline for receipt of applications is August 1, 1981.

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In addition, applicants are invited to submit research proposals detailing the general research directions and specific projects which they would wish to pursue. Further information concerning the position can be obtained directly from Dr. S. R. Taylor.

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2. Narrow and wide angle reflection seismology applied to continental crustal geology.
3. Wave propagation theory and techniques of seismic data analysis.

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Robert A. Phinney
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The position is under the auspices of a joint program of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) and the Interamerican Development Bank (IDB). It will be initially of medium duration, and is renewable.

It will be located at Bahía Blanca. Salary and fringe benefits according to qualification. Knowledge of Spanish language will be considered an advantage. For consultations or submitting applications, contact:

Señor Presidente del Consejo Nacional de Investigaciones Científicas y Técnicas
Avda. Rivadavia 1917
(1033) Buenos Aires, Argentina.

Applications should include complete academic and professional background along with a list of publications as well as names and addresses of three references.

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Peter Styles, Steven T. Suss, Kendall L. Svendsen.
 Pradeep Talwar, Michael A. Tamerin, Te-leng Teng, H. R. Thierstein, Ronald J. Thomas, T. R. Topporazda, Donald L. Turcotte, Pat Vanleek, Kenneth L. Verosub, Thomas A. Vogel, Eilatris G. Vornvoris, Carl A. Von Hake, William B. Wadsworth, Hare S. Walli, Mary Emma Wagner, Clyde Wahrhaftig, Raymond J. Walker, C. Wang, Steve Wegener, Ray F. Weiss, J. E. White, John M. Wilcox, James G. Williams, John Wilson, W. P. Winn, J. J. Won, David D. Woodbridge, Francis T. Wu, Shi Tien Wu, Klaus Wyrlik, Gouri Tsyh Yeh, Hsueh-Wen C. Yeh.

Meetings

Applied Glaciology Symposium

The International Glaciology Society has elected its second meeting on the applied aspects of snow and ice research for August 23-27, 1982, at the Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. This Second Symposium on Applied Glaciology will include technical sessions on the engineering problems of floating ice; engineering problems of ground ice; icebergs and glaciers; properties and behavior of snow and ice; snow removal and control; avalanche control and snow pressure; ice accretion; and modeling techniques in applied glaciology.

For additional information, contact the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom. ☐

Coastal Engineering Conference

The 18th International Conference on Coastal Engineering will be held November 14-19, 1982, in Cape Town, Republic of South Africa.

Topics to be covered at the conference include wind current and wave action; tides and long waves; sedimentary processes and coastal morphology; estuary and inlet behavior; coastal structures and recreational facilities; ship motions and harbor entrance design; ocean outfall design and construction; and environmental aspects of coastal engineering.

Five copies of a synopsis (not to exceed two pages) of papers proposed for the conference should be sent to Billy L. Edge, Secretary, Coastal Engineering Research Council, Department of Civil Engineering, Clemson University, Clemson, SC 29631. Deadline is October 31, 1981. ☐

Underwater Mining Institute

The 12th Underwater Mining Institute is scheduled for October 20-22 in Madison, Wisconsin. The program will include presentations on mineralogy of marine sulfide deposits; tectonic setting for spreading center sulfide deposits; seafloor sulfides in the Galapagos and other Pacific areas; new developments in southern Asia offshore tin operations; geophysical techniques for finding underwater copper lodes; new geochemical techniques for marine mineral exploration; changes in the international mining trade of relevance to marine mining; and the impact of sea grant mineral research on industry. The program will also include tours to local research laboratories.

For registration information, contact Gregory Hedden, Sea Grant Advisory Services, University of Wisconsin, 1815 University Avenue, Madison, WI 53706 (telephone: 608/262-0644).

For technical program information, contact J. Robert Moore, Marine Science Institute, University of Texas, P.O. Box 7999, University Station, Austin, TX 78712 (telephone: 512/471-4818). ☐

AGU Midwest Meeting

September 17-18
 Minneapolis, Minnesota

Abstract Deadline: July 1
 Convenor: V. Rama Murthy

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Marine structure and dynamics. Contact Geoffrey Davies or Clem Chase.
Rock water interactions: Hydrothermal processes and metamorphism. Contact William Seyfried.
Precambrian crustal evolution of the North American continent. Contact Paul Walbran.
Geomagnetism and paleomagnetism. Contact Subir Banerjee.
Hydrology in the mid-continent U.S. Contact H. O. Plattner or E. C. Alexander, Jr.

Abstracts

Use standard AGU format (see page 20 of January 13 EOS) and send original and two copies of abstract to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in EOS, with a substantive meeting report after the meeting. There will be no abstract charge.

Aquifer Protection Policies

A special program entitled "Effects of New Aquifer Protection Regulations and Policies on Ground Water Management" will be held at the American Society of Civil Engineers' Spring Convention and Exhibit during the week of April 19, 1982, in Las Vegas, Nevada. The program is sponsored by the Hydraulic Division's Committee on Ground Water Hydrology and by the Environmental Engineering Division's Committee on Hazardous Waste Management.

A call for papers has been issued for the following topics: review of regulatory activity; future protection regulations and policies; groundwater quality monitoring; design of well networks; groundwater studies stemming from regulations, including remedial measures; and ongoing and needed research. Research topics should address pollution sources, transport and fate of pollutants, methods of detection, and aquifer rehabilitation.

Geophysicists interested in presenting a paper should send a one-page abstract to Richard J. Schlicht, Illinois State Water Survey, 805 East Springfield Avenue, P.O. Box 5050, Urbana, IL 61820 (telephone: 217/333-2594). Deadline is July 31. ☐

Workshop on Remote Measurement of Underwater Parameters

This workshop was held at Balesja, Norway, October 30 to November 1, 1980. It was arranged by the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division; Institute of Geophysical Research, University of Bergen; and Office of Naval Research, Arlington, Virginia. It was sponsored by the Royal Norwegian Council for Scientific and Industrial Research, the North Atlantic Treaty Organization, and the Office of Naval Research.

One may conclude from the meeting that the idea that it may be possible to determine any subsurface variables of the ocean by remote sensing is attractive in principle, but realizable now, in a severely limited manner, and still possible of advancement. Sound waves are now used for tracking SOFAR floats to map out deep and mid-level currents, and acoustic tomography offers possibilities that are now being explored in the field, with the first tentative results now being reported. Acoustic tomography measures a combination of velocity and sound speed fields over the water column, and the data can be interpreted to give mean variables and a number of integral measures of water properties as well as statistical measures of the field of variables. The upper mixed layer is not so well sampled by acoustic tomography, so for the upper layer, one will have to rely upon other methods. In seawater, electromagnetic waves cannot be used profitably; for brackish or fresh water overlying salt water, radar monopulse methods offer some promise. These methods are in routine use for ice profiling on lakes and rivers, and extension to estuaries may prove useful and practical.

Satellite interrogation of drifters, and shore station tracking of drifting buoys are other methods of obtaining information about the ocean without having to go there each time one wants information.

Among the active methods of sensing variables in the upper ocean are ground wave and ionospheric scatter radar. The ground wave radar method, one example of which is CODAR, when used from shore, can sense the current field in the upper 1/2 meter of the ocean with a spatial resolution of 1.5 km² and 0.10 m/s. While a few examples were given of synthetic aperture radar (SAR) signatures in SEASAT-SAR data, the processing algorithm was not described in sufficient detail to enable one to make any judgment about the method, although in principle it should be possible to infer current along one direction from Doppler-shifted reflections. The SAR data also show a strong correlation between bathymetry and sea surface roughness. As of previous workshops where these data have been presented, there was little, if any, analysis given of the dynamic light sources, like advantage of the following effects: the broadening is temperature dependent; thus, one may be able to measure temperature by observing the reflected light from pulsed, range-gated lasers.

Next comes Raman backscatter for measurements of salinity, temperature, and other variables, and then comes Brillouin scattering to sense sound velocity. When a very intense laser signal hits the water, it will also heat it and generate an acoustic signal. The reflection of the acoustic signal back to the surface (by density structures) will in turn generate a measurable surface signature. One can use this for depth sounding from airplanes and, ultimately, from even more remote platforms. The combination of possibilities, although few of them are now at a stage ready for routine practical use, suggests that one should follow developments closely. The methods, so far, seem to be mainly useful in the upper 50 m of the ocean but may some day be extended to several times that depth. This will tell us very little about the deeper water column. But the possibility of obtaining synoptic data, even in the upper few meters, seems interesting. The technology needs to be worked out, and the oceanographic community need not yet hold its collective breath and sit around and wait, but the new methods may be upon us in a few years. The active and passive remote sensing of water properties has, of course, also been extended to sensing of biological properties. Here the workshop contained a very interesting set of papers on algorithms and the inverse problem and an example of application of color measurement to mud flat and algal flat properties.

The first paper was by N. K. Hejerslev, who showed that different regions of the ocean have sufficiently different plankton-related color that a universal algorithm for interpreting color in terms of biological measures will have serious shortcomings. The next paper, by J. Fischer and H. Grasse, who had examined the problem of remote sensing of particulates, found that the problem of determining particulate matter variables from color observations was not well conditioned and that the matrix really had only two linearly independent characteristic vectors. The tentative conclusion of little interest to these two papers was that before one can use color to determine biological variables, one needs to introduce some information about local biological properties as a constraint on the inversion process. This means that one needs biologists to help with the interpretation; one cannot find a way where the technology system and the computer can do it all by themselves. This should not be a source of wonder because biology is a non-linear branch of science and cannot be left to automation. One has to develop a certain judgement and expertise before one can produce useful results.

The Coastal Zone Color Scanner provides useful information for biologists, but the information from the intensity of color bands cannot be used blindly, it has to be interpreted through the use of knowledge about local biology as a constraint on the inversion process. An example of how to incorporate local knowledge in an inversion problem was given by Prober, Bahr, and Dennert-Müller, who interpreted the LANDSAT images from different channels, in terms of ideal flat classes, including dry sand, wet mud, and others by using "training fields" and in situ establishment of field characteristics. The use of these training fields introduced the local constraint on the inversion process and made it possible to classify a large region from LANDSAT data after field work in a limited area that covered the important classes of flats.

This is apparently the direction in which one has to seek methods for interpreting upper ocean color. Also, no doubt, the same method can be used with active sensors, where one senses the color quality of reflection of laser lights from different depths, including fluorescence effects.

While some of the methods seemed kind of far from practical realization in the near future, there is rapid technology development under way.

The workshop was informative for the participants, and the sober assessments provided by the working groups showed that one cannot dismiss remote sensing techniques out of hand, that the technologists need to encounter scientists to learn what one should look for, and it showed how one may edify oneself with knowledge to remote sensing data. In that sense the workshop was educational, realistic, and productive of sober evaluations of methods. An abstract volume will be available shortly from the Royal Norwegian Council for Scientific and Industrial Research, Space Activity Division, P.O. Box 309, Blindern, Gaustadallen 30 D, Oslo, 3, Norway.

This meeting report was prepared and submitted by Erik Molva-Christensen of the Department of Meteorology and Physical Oceanography at MIT, Cambridge. ☐

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Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

May 27-29 Canadian Meteorological and Oceanographic Society 15th Annual Congress, Saskatoon, Saskatchewan, Canada. (S. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Outpost Street, Downsview, Ontario M3H 6T4 Canada.)

June 1-4 First JECSS Workshop Tokyo, Japan. Sponsor, Teikoku University, (Takashi Ichijo, Dept. of Oceanography, Teikoku University, College Station, TX 77843.)

June 1-5 Second International Symposium on Remote Sensing Technology for Surveying and Geodesy, Banff, Canada. Sponsors, AGU, Canadian Institute of Surveying, Univ. of Calgary, (Klaus-Peter Scherz, ISS Symposium 1981, Division of Surveying Engineering, Univ. of Calgary, Calgary, Alberta T2N 1N4 Canada.)

June 3-4 Symposium on the Ecology and Management of Reservoirs, Université Laval, Québec, Canada. Sponsors, Université Laval, Université du Québec, Université Laval, Hydro-Québec, Société d'Énergie de la Baie James. (P. G. Campbell, Université du Québec, INRS-Eau, C.P. 7500, Ste. Foy, Québec G1V 4C7 Canada.)

June 4-5 Eastern Snow Conference, Syracuse, N.Y. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Outpost Street, Downsview, Ontario M3H 6T4 Canada.)

June 7-11 Eighth Ocean Energy Conference for the Department of Energy, Washington, D.C. Sponsor, Marine Technology Society. (Harry Irwin, Marine Technology Society, 1730 M St., N.W., Washington, DC 20038.)

June 8-10 International Geoscience and Remote Sensing Symposium, Washington D.C. Sponsors, AGU, IEEE Geoscience and Remote Sensing Society. (F. T. Uebay, Remote Sensing Laboratory, Univ. of Kansas Center for Research, Inc., West Campus, Lawrence, KS 66045.)

June 14-19 Second International Conference on Urban Storm Drainage, Urbana, IL. Sponsors, Univ. of Illinois, International Union in Urban Storm Drainage, International Association of Hydraulic Research, International Association of Water Pollution Research, American Society of Civil Engineers. (B. C. Yen, Department of Civil Engineering, Univ. of Illinois, Urbana, IL 61821.)

June 15-19 International IEEE/APS Symposium, National Radio Science Meeting, and International IEEE/MTT Symposium, Los Angeles, Calif. (P. N. G. Alexopoulos, 7732 Sceller Hall, Department of Electrical Sciences, Univ. of California, Los Angeles, CA 90024.)

June 22-26 International Symposium on Erosion and Sediment Transport Measurement, Florence, Italy. Sponsors, IAHS, International Commission on Continental Erosion, National Research Council of Italy. (P. Tacconi, Secretary of the Organizing Committee, Istituto di Ingegneria Civile Via S. Maria, 3 50139 Firenze, Italy.)

June 23-26 Seventh International Symposium on the Machine Processing of Remotely-Sensed Data, West Lafayette, Ind. Sponsor, Laboratory for Applications of Remote Sensing, Purdue Univ. (D. B. Morrison, Purdue Univ./IARS, 1220 Potter Dr., West Lafayette, IN 47909.)

June 24-28 International Symposium on Real-Time Operation of Hydrosystems, Waterloo, Ontario, Canada. Sponsor, Water Resources Group, Univ. of Waterloo. (T. E. Unny or E. A. McBean, Univ. of Waterloo, Department of Civil Engineering, Waterloo, Ontario N2L 3G1 Canada.)

June 29-July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology, (Barbara Duffee, Coordinator, Center for Advanced Engineering Study, Cambridge, MA 02139.)

June 29-July 3 Conference/Workshop on Heterogeneous Catalysis—Its Importance to Atmospheric Chemistry, Albany, N.Y. Sponsors, NSF, NASA. (V. A. Mohner, Atmospheric Sciences Research Center, State Univ. of New York, Albany, NY 12222.)

June 29-July 11 Seminar on Fluid-Dynamical Problems in Astrophysics and Geophysics, Chicago, Ill. Sponsors, American Mathematical Society, Society for Industrial and Applied Mathematics. (Meeting Arrangements Department, American Mathematical Society, Post Office Box 6248, Providence, R.I.)

July 6-11 Geoscience '81-South African Geomorphology Project and 3rd International Platinum Symposium, Pretoria, South Africa. Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat S. 217, CSIR, P.O. Box 985, Pretoria 0001 Republic of South Africa.)

July 8-10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsors, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 16-17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Bucher, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21-23 Chapman Conference on Spatial Variability in Hydrologic Modeling, Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20008.)

July 21-30 21st General Assembly of IA-SPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27-30 Eighth International Symposium on Urban Hydrology, Hydrodynamics, and Sedimentation, Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 206B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug. 3-16 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug. 4-7 International Conference on Energy Education, Providence, R.I. (Donald Kirwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9-15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, ICCL, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 9-19 International Congress of Surveyors, F.I.G., Montreux, Switzerland. Sponsor, Fédération Internationale Des Géomètres. (American Congress on Surveying and Mapping, 210 Little Falls Street, Fells Church, VA 22046.)

Aug. 10-14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10-14 Water Forum '81: Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage. (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22044.)

Aug. 10-19 20th General Assembly of the International Union of Radio Science, Washington, D.C. (R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20419.)

Aug. 17-23 Third Scientific Assembly of IAGAP with Extraordinary General Assembly, Hamburg, Federal Republic of Germany. (S. Rutenburg, NCAR, P.O. Box 3000, Boulder, CO 80507.)

Aug. 17-19 Open Symposium on Mathematical Models of Radio Propagation, Washington, D.C. Sponsors, URSL, (J. R. Wall, Bldg. 20, Electrical Engineering Department, Univ. of Arizona, Tucson, AZ 85721.)

Aug. 17-22 Ninth International Symposium on Earth Tides, New York, N.Y. Sponsors, IAGU, IUGG, Columbia Univ. (J. T. Kuo, 828 S.W. Mudd, Columbia Univ., New York, NY 10027.)

Aug. 18-21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Heigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5081.)

Aug. 20-21 Second International Symposium on Computer-Aided Seismic Analysis and Discrimination, North Orem, Utah. Sponsors, Electrical Engineering Department, Southeastern Massachusetts University, IEEE Computer Society, IEEE Acoustics, Speech and Signal Processing Society. (C. H. Chen, Electrical Engineering Department, Southeastern Massachusetts University, North Dartmouth, MA 02747.)

Aug. 24-28 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodetic Institute. (C. C. Teichmeyer, International Symposium Management, Gamlehave Alle 10, Geodetisk Institut, Copenhagen 22, Charlottenlund OK-220 Denmark.)

Aug. 24-29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (G. E. Lund, Chairperson Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 558, 22 Uppsala, Sweden.)

Aug. 26-27 The Royal Institution of Chartered Surveyors Centenary Celebration, London, England. (Representative Rad-Inet), American Geophysical Society, Uppsala, Sweden. (G. E. Lund, Chairperson Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 558, 22 Uppsala, Sweden.)

Aug. 28-Sept. 9: Aro Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan. (IAGVCEI, Daijishu)

Shimozuru, IAGVCEI Symposium on Aro Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31-Sept. 2 Third International Colloquium on Mars, Pasadena, Calif. Sponsors, NASA, Lunar and Planetary Institute, Division of Planetary Sciences of the AAS. (Convey W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109.)

Aug. 31-Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 München 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairmen of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c/o LNEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7-12 Third International Symposium on Antarctic Glaciology, Columbus, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society, (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 13-12 American Society of Photogrammetry-American Congress on Surveying and Mapping Fell Convention, San Francisco, Calif. (L. W. Aggers, USGS, 345 Middlefield Road, Mail Stop 31, Menlo Park, CA 94025.)

Sept. 13-17 National Water Well Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 18-19 Oceans '81, Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering, AGU. (R. Nagle, Publicity Manager, Reytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 17-19 Midwest Meeting, Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept. 17-19 Pacific Northwest Regional Meeting, Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 99502.)

Sept. 20-22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 28-Oct. 10 NATO Advanced Study Institute on Chemistry of the Unpolluted and Polluted Troposphere, Corfu, Greece. (W. Jaeschke, Center of Environmental Protection, University of Frankfurt, Robert-Meyer-Str. 11, 6000 Frankfurt/Main, FRG.)

Oct. 6-9 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario, Canada. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. El-Sherawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 11-14 Coastal Society's Seventh Annual Conference, Galveston, Tex. (N. West, Coastal Society Conference, Department of Geography and Marine Affairs, Univ. of Rhode Island, Kingston, RI 02881.)

Oct. 11-15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 448, La Brea, CA 90031.)

Oct. 13-15 Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, La. Sponsors, Louisiana Geological Survey, Department of Natural Resources; Energy Programs Office, Louisiana State University; U.S. Department of Energy. (Ann Bachman, Conference Coordinator, Energy Programs Office, 105 Hill Memorial, Louisiana State Univ., Baton Rouge, LA 70803.)

Oct. 13-16 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hapke, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14-19 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 833 Sixth Ave., S.W., Calgary, Alberta, Canada T2P 2V5.)

Oct. 22-24 Fourth Conference on the Physics of the Jovian and Saturnian Magnetospheres, Laurel, Md. Sponsor, NASA. (S. M. Krimigis, Applied Physics Laboratory, Johns Hopkins Univ., Laurel, MD 20810.)

Oct. 28-30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shoreline Commission of the International Union for Quaternary Research, Scientific Committee of the World Confederation of Underwater Activities. (Patricia M. Morton, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

November 1-5 Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oregon. Sponsor, Estuarine Research Federation. (Jay F. Watson, Treasurer, USFWS Suite 1982, 500 N.E. Multnomah Street, Portland, OR 97232.)

Nov. 2-6 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Ames Research Center, Moffett Field, CA 94035.)

Nov. 8-11 Special Conference on the Mechanical Behavior of Salt, University Park, Pa. Sponsor, Rock Mechanics Laboratory, Department of Mineral Engineering, Pennsylvania State University. (H. Reginald Hardy, Jr., Rock Mechanics Laboratory, Penn State Univ., University Park, PA 16802.)

Nov. 9-20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAGU, IUGG Local Committee of Kenya. IUGG Committee on Advice to Developing Countries, African Association of Cartography. (R. Omandi, Survey of Kenya, P.O. Box 30046, Nairobi, Kenya.)

Nov. 30-Dec. 1 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM Research Division, Box 219, Yorktown Heights, NY 10598; or G. S. Watson, Barnouli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08541.)

Dec. 3-5 Topical Conference on the Processes of Planetary Rifting, San Francisco, Calif. Sponsors, Lunar and Planetary Institute. (Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77056.)

Dec. 7-11 AGU Fall Meeting, San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 18-19 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluoni, Istituto di Petrologia, Via Gramsci 9, 43100 Parma, Italy.)

Geodynamics Series Volume 1



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Feb. 8-12 Third International Geodetic Symposium on Satellite Doppler Positioning, Las Cruces, N. Mex. Sponsors: Delano Mapping Agency, National Ocean Survey, AGU, (Richard Paal, Delano Mapping Agency, Hydrographic/Topographic Center, 8500 Brooks Lane, N.W., Washington, DC 20315).

Feb. 15-19 Ocean Sciences AGU/ASLO (American Society of Limnology and Oceanography) Joint Meeting, San Antonio, Tex. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20008).

Mar. 22-28 International Symposium on Hydrothermal Reactions, Yokohama, Japan. Sponsors: Tokyo Institute of Technology, (Shigeyuki Saito, Research Laboratory of Engineering Materials, Tokyo Institute of Technology, Meguro-ku, Midori, Yokohama, 227 Japan).

Apr. 11-18 Penrose Conference on Antarctica, Shenandoah National Park, Va. Sponsors: GSA, (Jan W. D. Zolner, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY 10964).

April 18-21 Cordilleran Science, Geological Society of America Annual Meeting, Anaheim, Calif. (National Mineral Resources Department, California State Univ., Fullerton, CA 92634).

May 3-7 14th International Liege Colloquium on Ocean Hydrodynamics, Liege, Belgium. Sponsors: IAPSO, Unesco Marine Sciences Division, EGS, Intergovernmental Oceanographic, AGU, (Jacques C. J. Nihoul, University of Liege, Mécanique des Fluides Géophysiques, Environnement, 68- Sart Tilman, B-4000 Liege, Belgium).

May 7-20 Gonori Meeting of IAG, Tokyo, Japan. (I. Nohgawa, Gonori Institute of Technology, Kyoto University, Sakyo-ku, Kyoto 608 Japan).

May 10-12 Fourth International Conference on Planning and Management of Water Resources for Industrial, Agricultural, and Urban Use, Marseille, France. Sponsors: Commission Européenne Méditerranéenne de Planification des Eaux (C.E.M.P.E.), Société des Eaux de Marseille (S.E.M.), le Bureau de Recherches Géologiques aux Minères (B.R.G.M.), Centre de Formation Internationale à la Gestion des Ressources en Eau (CEGIRE), UNESCO, Commission des Communautés Européennes, Association des Hydrologues (AIH), Secrétariat de la Conférence, Société des Eaux de Marseille, 25 rue Edouard Delandelle—13008 Marseille, France).

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June 27-July 2 Fifth International Conference on Geochronology, Cosmochemistry, and Isotope Geology, Nikko National Park, Japan. (K. Shiohara, Geological Survey of Japan, Higashi 1-1-3, Yotsube, Ibaraki 305 Japan).

July 19-20 Scientific Meeting of IAHS with Extraordinary General Assembly, Exeter, United Kingdom. (John C. Rodda, Department of the Environment, Water Data Unit, Reading Bridge House, Reading RG1 8PS United Kingdom).

Aug. 2-13 Joint Oceanographic Assembly, Halifax, Nova Scotia, Canada. Sponsors: Scientific Committee on Oceanic Research, (Leo O'Quinn, National Steering Committee for JOA, c/o Canadian Committee on Oceanography, 240 Sparks St., Ottawa, Ontario K1A 0E6 Canada).

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